RF and Microwave Products Induction Program by

Md Mussavir (BE. ECE)

- : Product/Application Support

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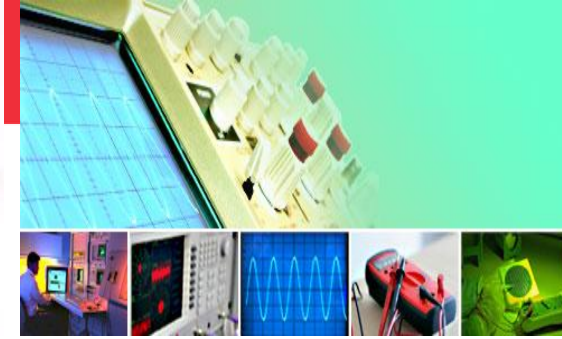
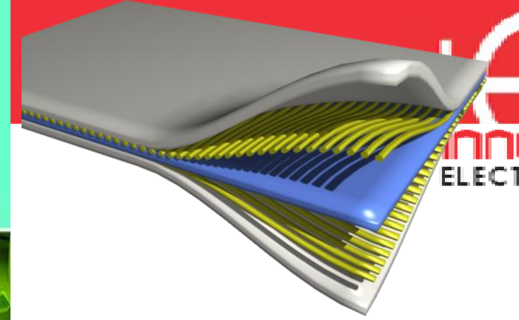
RF and Microwave



Test and Measurement



Specialty Materials

Innovate Electronics Corporation promoted by experience professionals from the composites and RF & Microwave industry. Focused in promotion of Composites specialty materials. RF & Microwave components, sub systems to Indian Aerospace, Defense & Avionics industry. Our product and market knowledge, coupled with our ability to share information, makes us unique in the industry. We consider our customers, manufacturers representatives, vendors, and team members to be partners.

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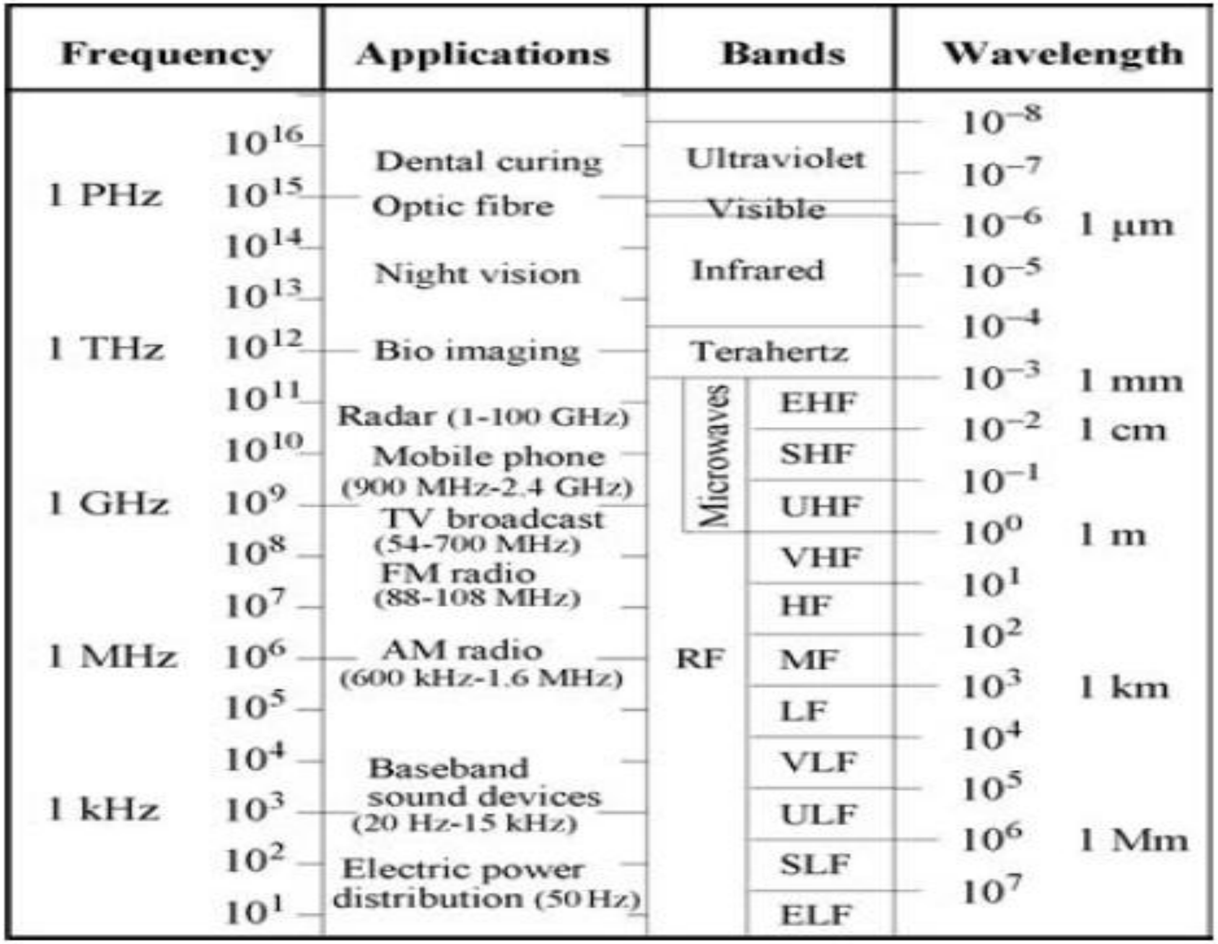


Figure 1.1 The electromagnetic spectrum.

Band	Frequency range
HF Band	3 to 30 MHz
VHF Band	30 to 300 MHz
UHF Band	300 to 1000 MHz
L Band	1 to 2 GHz
S Band	2 to 4 GHz
C Band	4 to 8 GHz
X Band	8 to 12 GHz
Ku Band	12 to 18 GHz
K Band	18 to 27 GHz
Ka Band	27 to 40 GHz
V Band	40 to 75 GHz
W Band	75 to 110 GHz
mm Band	110 to 300 GHz

Table 1.1 Denomination of radio bands.

Band	Denomination	Frequency range	Wavelengths
1	ELF	< 30 Hz	>10 000 km
2	SLF	30–300 Hz	10 000–1000 km
3	ULF	300 Hz–3 kHz	1000–100 km
4	VLF	3–30 kHz	100–10 km
5	LF	30–300 kHz	10–1 km
6	MF	300 kHz–3 MHz	1 km–100 m
7	HF	3–30 MHz	100–10 m
8	VHF	30–300 MHz	10–1 m
9	**UHF**	**300 MHz–3 GHz**	**1 m–10 cm**
10	**SHF**	**3–30 GHz**	**10–1 cm**
11	**EHF**	**30–300 GHz**	**10–1 mm**
12	LHF	>300 GHz	< 1 mm

Table 1.1 lists the frequency band designations according to the CCIR (Consultative Committee on
International Radio) over the full 30 Hz to 300 GHz spectrum

Table 1.2 IEEE denomination of microwave frequency bands.

Denomination	Frequency range (GHz)
UHF	0.3–1
L	1–2
S	2–4
C	4–8
X	8–12
Ku	12–18
K	18–27
Ka	27–40
V	40–75
W	75–110
Millimetre waves	30–300
Submillimetre waves	300–3000

Why/Why-not to go for Higher Frequencies

- The attenuation rapidly increases over 10 GHz with a non-monotonic behavior, reaching the peaks due to water vapor absorption at 22 GHz and oxygen absorption at 63 GHz, the minima of attenuation being located at 24 and 94 GHz.
- In general, as observed above, the use of ever higher frequencies is spurred by a number of advantages such as the reduced dimensions of the components (antennas, line sections, circuit elements), wider bandwidths, high signal processing and data transmission speeds, higher radar resolution, higher antenna directivities and thus reduced interference.
- By contrast, the use of higher frequencies involves a number of practical problems, such as higher atmospheric attenuation (although not necessarily), more stringent fabrication tolerances (because of the reduced dimensions), higher fabrication costs, higher circuit loss and reduced available power from the solid state devices, and lower or insufficient maturity of the semiconductor technology.

Applications

- RF and microwave technology, originally finalized for military applications (radar), is nowadays spurred by a number of civil applications, especially cellular telephony and the so-called personal communication systems (PCS). Communications remain the most important application area where, besides cellular telephony and satellite communications, we may include radio and television broadcasting, wireless local area networks (WLANs) and point–multipoint broadcasting systems, namely LMDS (Local Multipoint Distribution Systems) and MMDS (Multipoint Multichannel Distribution Systems).

- RF and microwave technology also concerns several application sectors including, among others:
  - Navigation and localization systems, such as GPS, based on 24 orbiting satellites and providing the user with geographical coordinates and height, or the corresponding European system Galileo, and aircraft landing systems such as MLS (Microwave Landing System).
  - Electromagnetic sensors for the measurement and characterization of physical quantities and the properties of materials for industrial applications.
  - Weather forecasting and remote sensing of environmental parameters (e.g. temperature, wind speed, water content) and monitoring of natural resources.
  - Automotive, road traffic aids and control.

- Civil and military surveillance systems.
- Healthcare and medicine, for investigation, diagnosis and treatment, such as microwave hyperthermia for treating cancer.
- Radio astronomy and space exploration.
- Microwave imaging, for civil and military applications.
- RF identification (RFID), a technique which is rapidly replacing the bar code system to identify and track products, animals or persons using RFs.
- Food processing, industrial treatment (drying, curing, heating, etc.) of materials and goods (e.g. for killing pests).

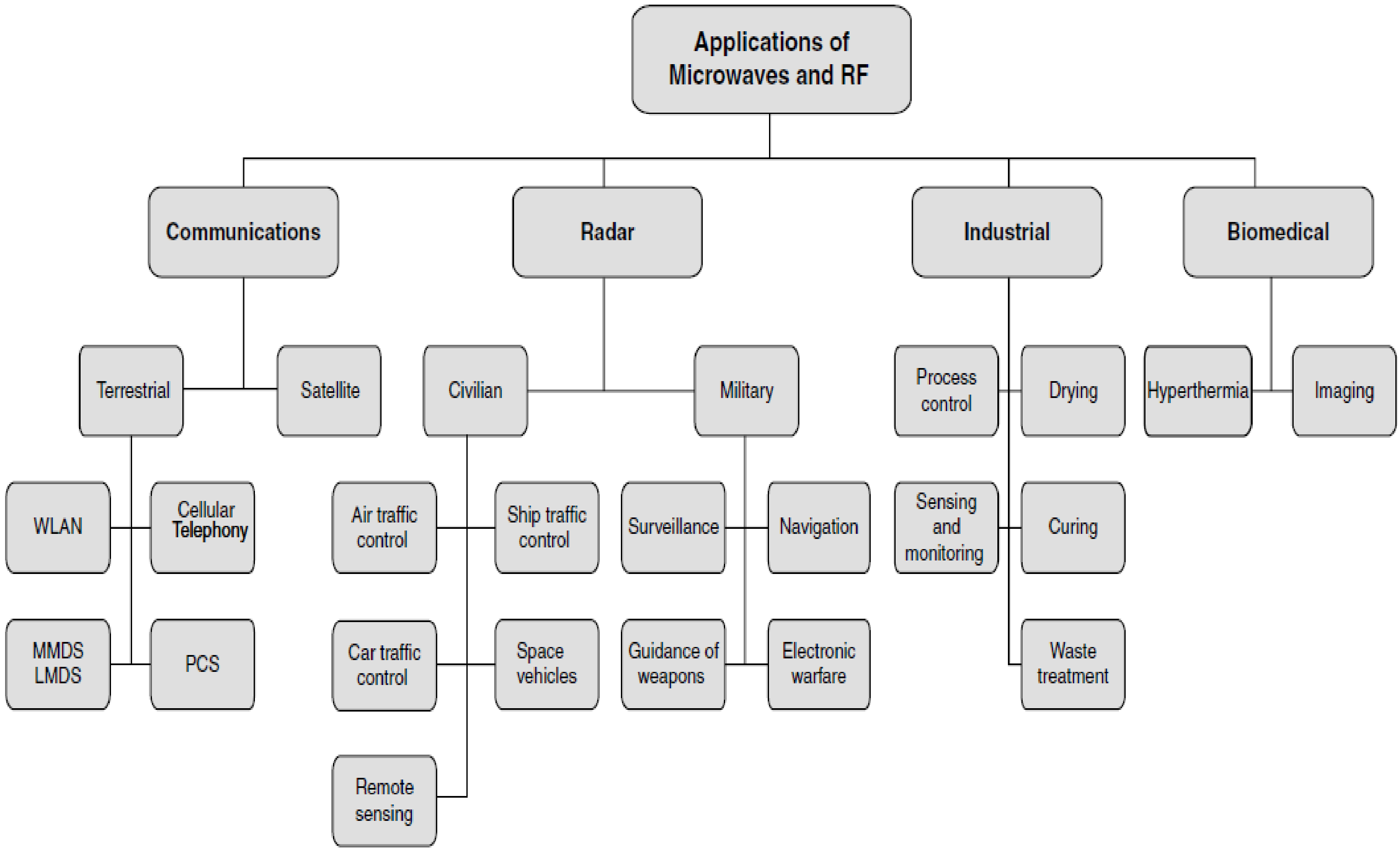


Figure 1.4 Applications of microwaves and radio frequencies.

Guided EM propagation

- Transmission lines are fundamental components of any RF apparatus or system. They are necessary to connect devices and components in order to transmit the RF signal from one point to the other. At RFs the passive components themselves behave as distributed elements made of transmission line or waveguide sections. Because of the high operating frequencies, in fact, the dimensions of the circuit elements are normally of the same order of magnitude as the wavelength.

- The most common transmission lines and guiding structures employed at RF and microwaves. On the one side, except for the circular dielectric waveguide where the EM field is confined by the dielectric discontinuity, we have conventional closed structures such as the coaxial cable and metal waveguides of various shapes, where the field is confined by metal walls. On the other side, we have planar, printed or integrated circuits fabricated on top of a thin dielectric substrate, such as the stripline or the microstrip line; because of their advantages in terms of reduced size, weight and cost, they are the most frequently employed transmission lines, except when the requirements of lowloss or high power can only be matched by the use of waveguides.

Some common transmission lines for RF and microwaves.

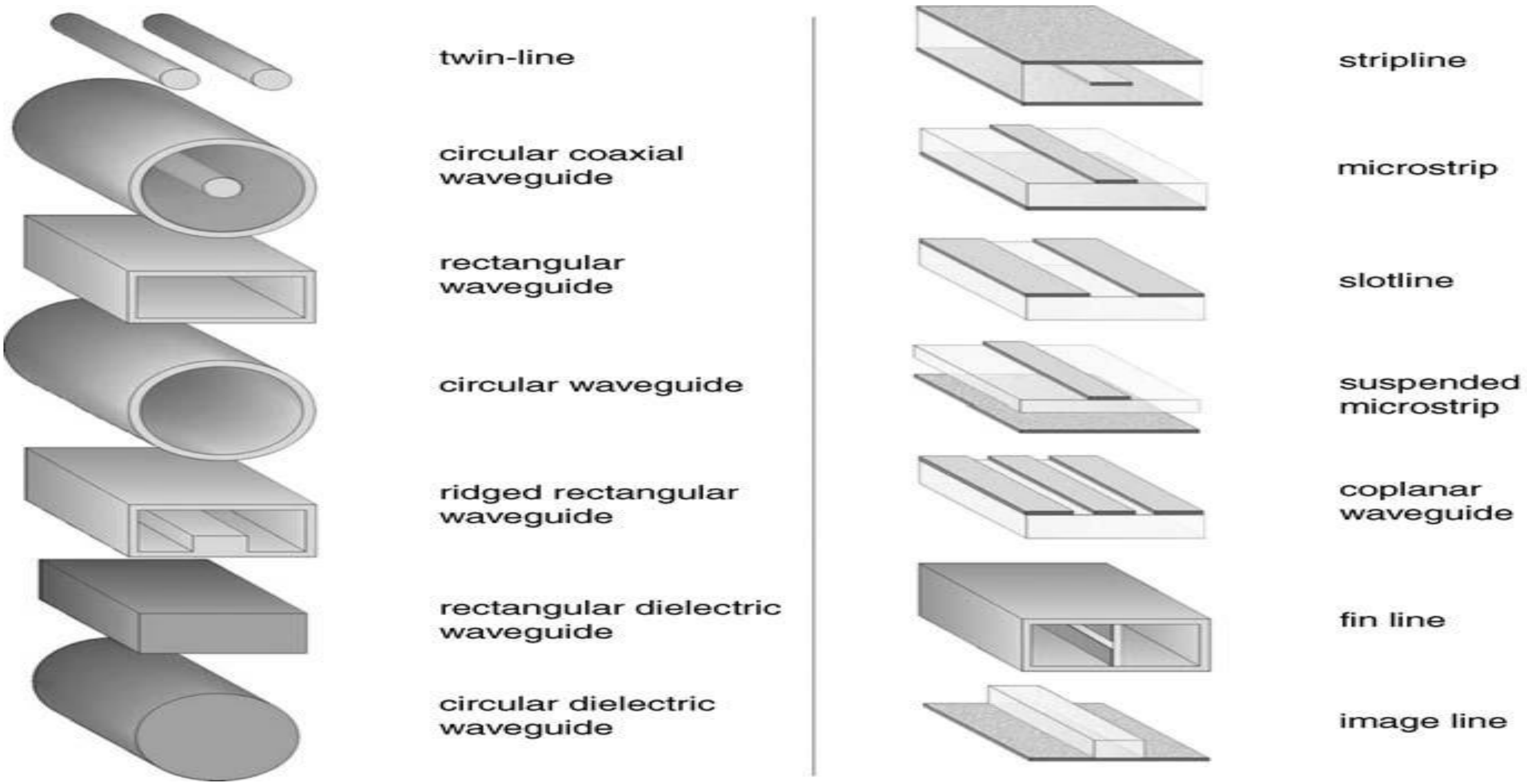


Table 3.1 Comparison between various types of transmission lines.

Transmission line	Usable frequency range (GHz)	$Z_0(\Omega)$	Q	Small size	Handled power	Compatibility with active devices	Low cost
Waveguide	1–300	100–500	++	−−	++	−	−
Coaxial cable	<50	10–600	+	−	+	−	−
Stripline	<20	10–120	−	0	0	0	0
Microstrip	<50	10–120	−	+	−	++	+
Coplanar line	<100	40–150	−	0	−	+	+
Slotline	<40	20–150	0	0	−	+	0
Suspended stripline	<50	30–200	+	−	0	0	+
Image line	10–300	30–200	++	0	−	−−	−

Legend: ++ very good; + good; 0 neutral; − poor; −− very poor.

Filters

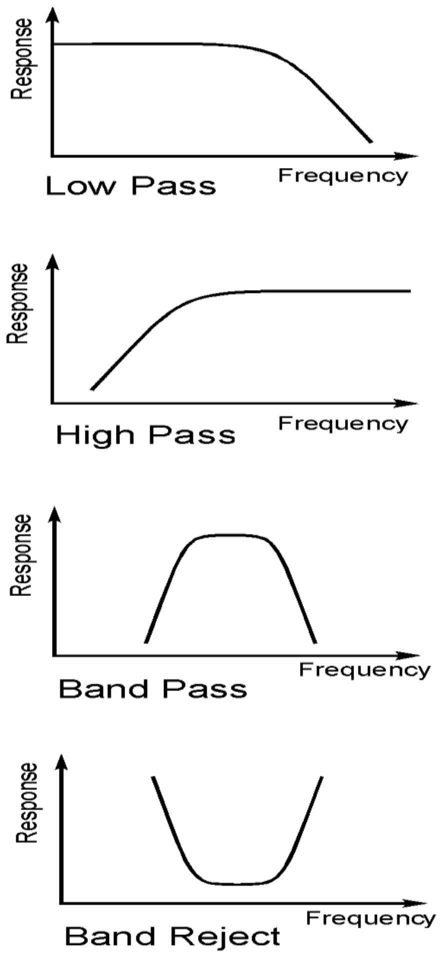
- What is a filter?
  - A filter is a two port network that exhibits some desirable frequency selective behavior. When connected between a source and a load, the filter allows power within certain frequency bands to be transferred substantially unattenuated from the source to the load, while in other frequency bands it prevents almost all the power from passing to the load.

- Microwave filters are loosely defined to operate in the microwave frequency range which is about 200MHz to about 90 GHz.

- RF filters of all types are required in a variety of applications from audio to RF and across the whole spectrum of frequencies. As such RF filters form an important element within a variety of scenarios, enabling the required frequencies to be passed through the circuit, while rejecting those that are not needed.
- The ideal filter, whether it is a low pass, high pass, or band pass filter will exhibit no loss within the pass band, i.e. the frequencies below the cut off frequency. Then above this frequency in what is termed the stop band the filter will reject all signals.
- In reality it is not possible to achieve the perfect pass filter and there is always some loss within the pass band, and it is not possible to achieve infinite rejection in the stop band. Also there is a transition between the pass band and the stop band, where the response curve falls away, with the level of rejection rises as the frequency moves from the pass band to the stop band.

Basic types of RF filter

- There are four types of filter that can be defined. Each different type rejects or accepts signals in a different way, and by using the correct type of RF filter it is possible to accept the required signals and reject those that are not wanted. The four basic types of RF filter are:
  - Low pass filter
  - High pass filter
  - Band pass filter
  - Band reject filter



- As the names of these types of RF filter indicate, a low pass filter only allows frequencies below what is termed the cut off frequency through. This can also be thought of as a high reject filter as it rejects high frequencies. Similarly a high pass filter only allows signals through above the cut off frequency and rejects those below the cut off frequency. A band pass filter allows frequencies through within a given pass band. Finally the band reject filter rejects signals within a certain band. It can be particularly useful for rejecting a particular unwanted signal or set of signals falling within a given bandwidth.

RF filter frequencies

- A filter allows signals through in what is termed the pass band. This is the band of frequencies below the cut off frequency for the filter.
- The cut off frequency of the filter is defined as the point at which the output level from the filter falls to 50% (-3 dB) of the in band level, assuming a constant input level. The cut off frequency is sometimes referred to as the half power or -3 dB frequency.
- The stop band of the filter is essentially the band of frequencies that is rejected by the filter. It is taken as starting at the point where the filter reaches its required level of rejection.

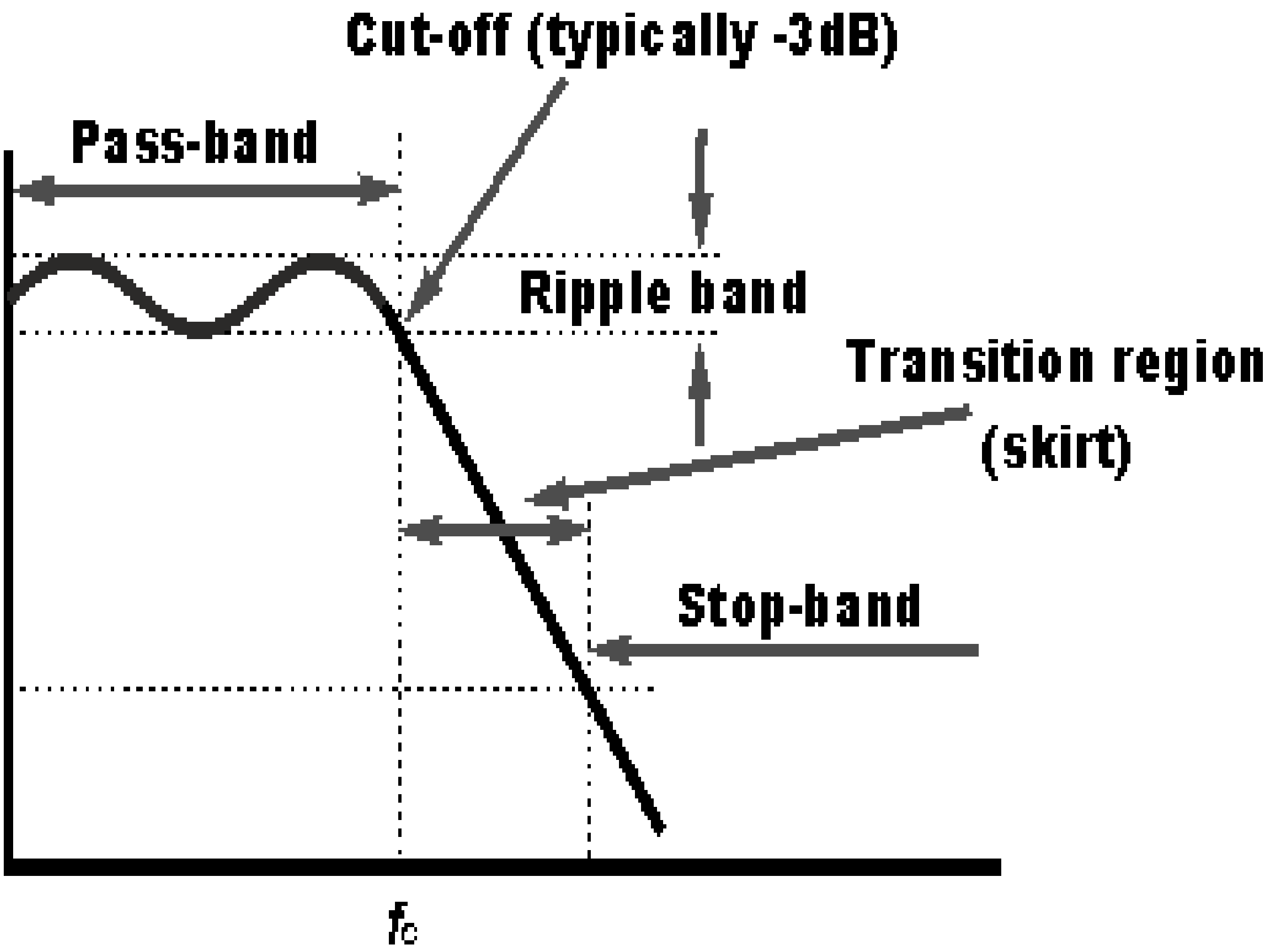
Key filter RF design parameters

- There are a number of key parameters that are of great importance for RF filter design. These are some of the highlight requirements for any RF filter design.
  - ***Pass-band:*** This is the region in which the signal passes through relatively un-attenuated. It is the band in a low pass filter, extends up to the cut-off frequency. For high pass filters it is designated as the band above which signal pass through, or for a band pass filter, it is the band between the two cut-off frequencies.
  - ***Cut-off frequency:*** This is normally taken to be the point at which the response of the filter has fallen by 3 dB. With certain filters, typically equi-ripple types such as the Chebyshev or inverse Chebyshev, the cut-off point has to be defined differently. It is often designated fc.
  - ***Ripple band:*** Within the pass-band, the filter response may show variations in its response - ripples. The variation is known as the ripple band

- ***Transition band:*** Once the RF filter response has gone beyond the cut-off point, the response falls away in a region known as the transition band. It is the region between the pass-band and the stop-band. This region is also sometimes referred to as the "skirt."
- ***Stop-band:*** This is the band where the filter has reached its required out of band rejection. The stop-band rejection may be defined as a required number of decibels.
- ***Number of poles :*** A pole is a mathematical term. There is one pole for each capacitor or inductor in a filter.

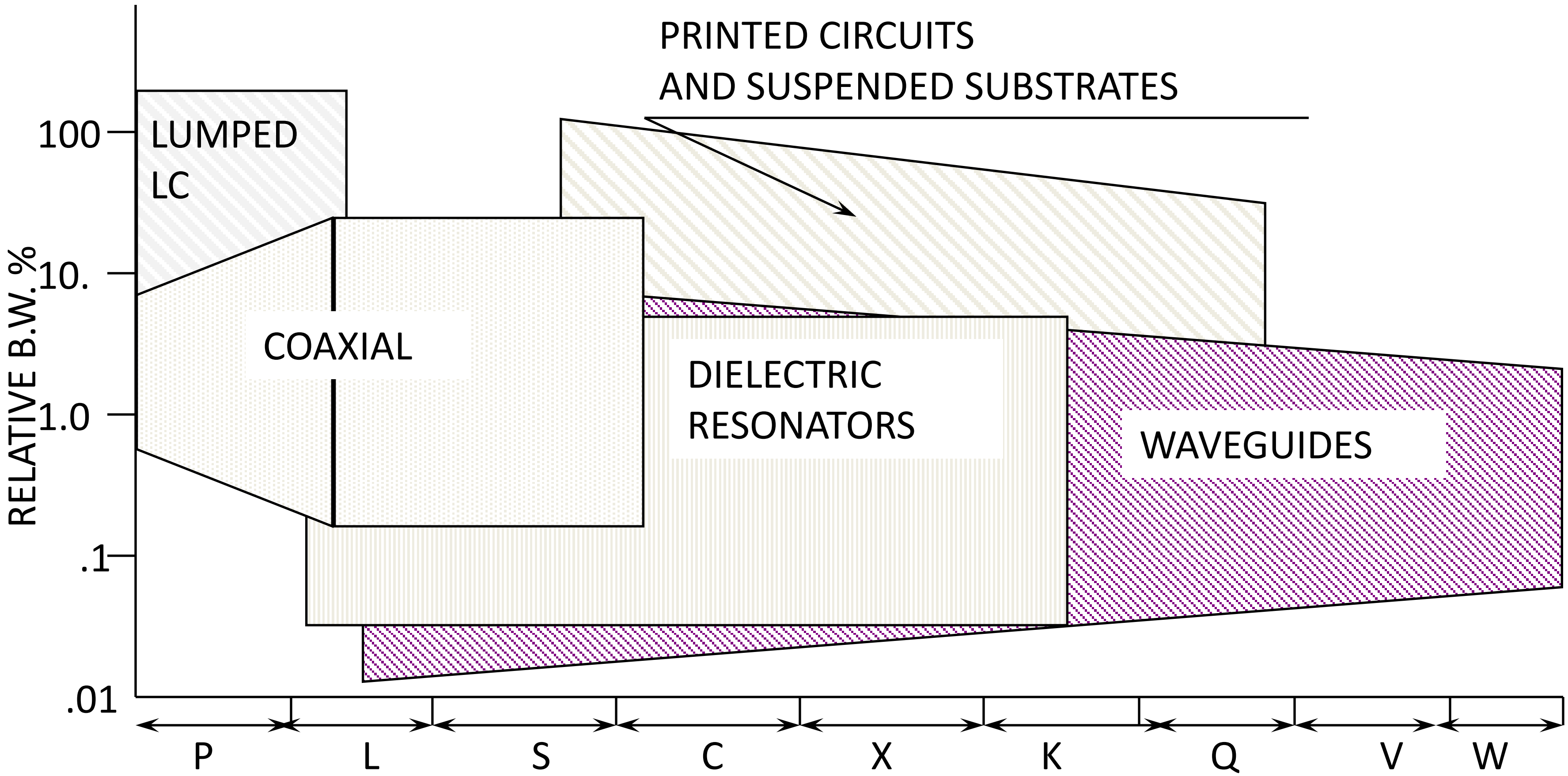
– ***Phase shift:*** The phase shift is another important factor for any RF filter design. It is accommodated into the overall response of the filter by considering the calculations for H(s) where s = jω. The phase response can be of importance to a waveform because the waveform shape will be distorted if the phase changes within the pass-band. A constant time delay corresponds to the phase shift increasing linearly with frequency. This gives rise to the term linear phase shift referred to in many RF filter designs.

– ***Impedance:*** Filters have a characteristic impedance in the same way that as an antenna feeder.


Cut-off (typically -3dB)
Pass-band
Ripple band
Transition region
(skirt)
Stop-band
fc

FILTERS TRANSMISSION MEDIA

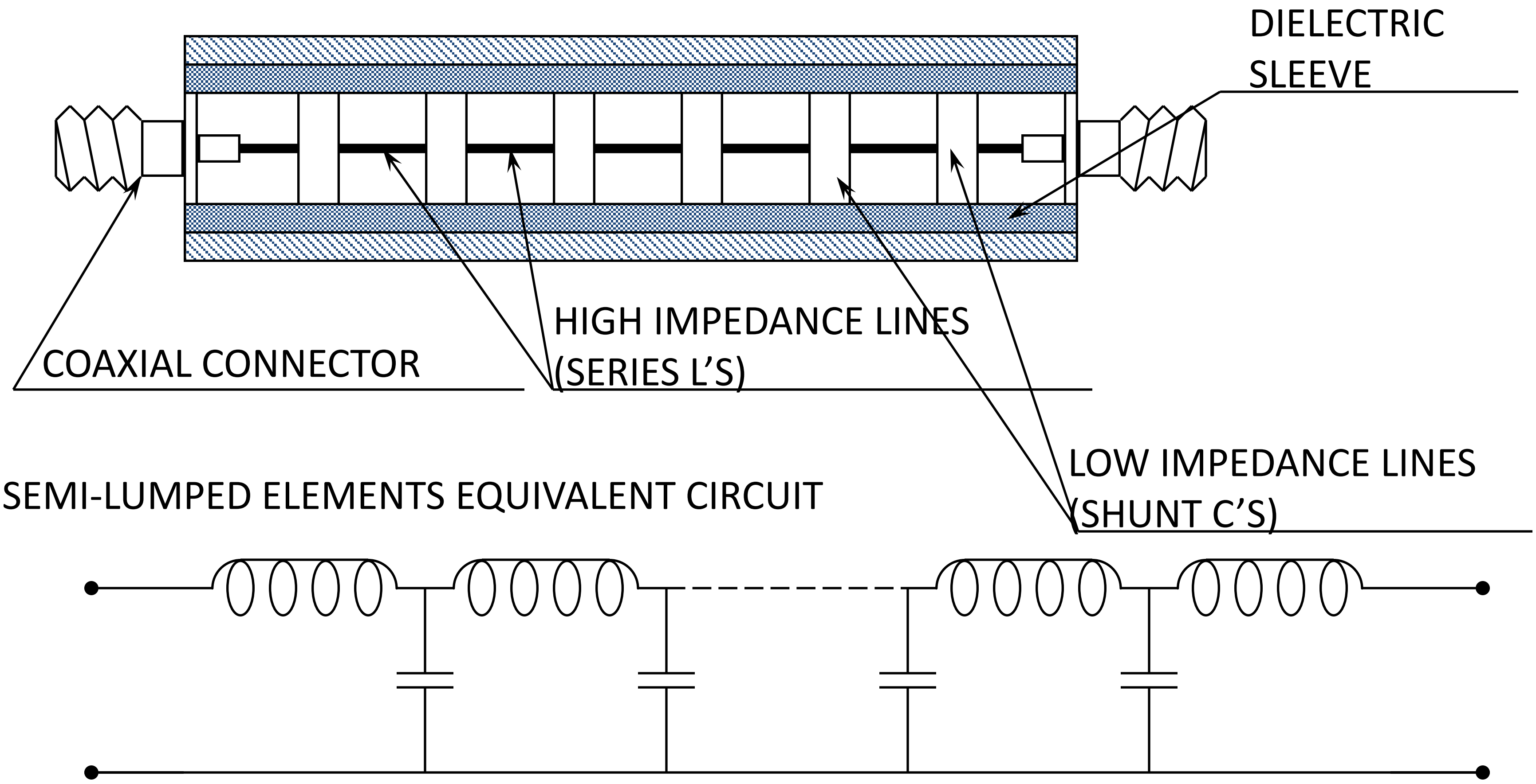
FREQUENCY BAND DESIGNATION



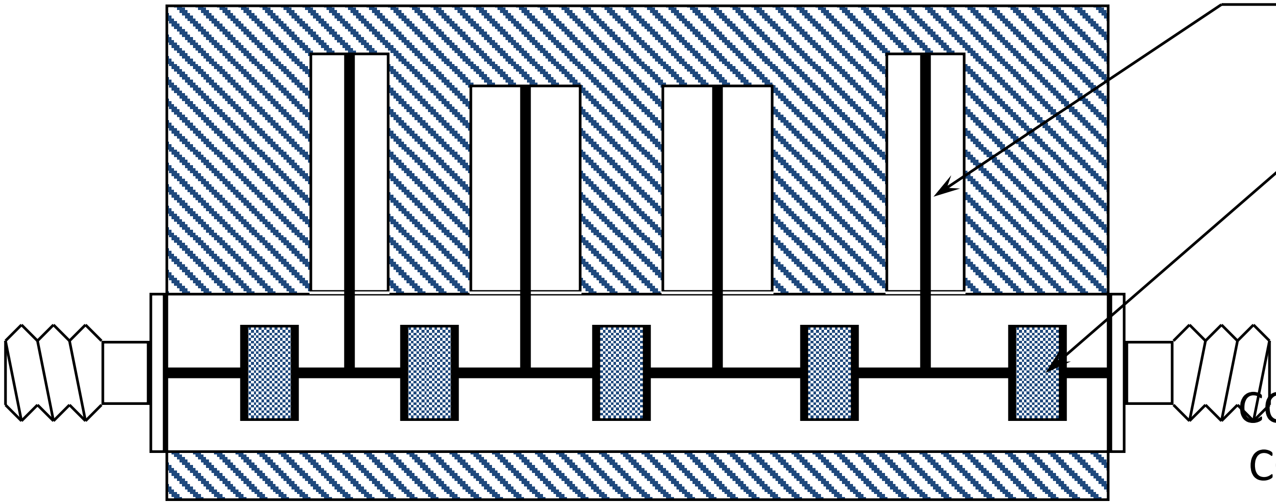
FILTER REALIZATIONS

- LOW PASS AND HIGH PASS SEMI-LUMPED ELEMENTS
  - COAXIAL
  - MICROSTRIP & STRIPLINE
- BAND PASS NARROW AND MODERATE BANDWIDTHS
  - COAXIAL “DUMBELL”
  - MICROSTRIP PARALLEL COUPLED AND END COUPLED
  - SUSPENDED SUBSTRATE
  - INTERDIGITAL, COMBLINE (COAXIAL)
  - WAVEGUIDES: RECTANGULAR, CIRCULAR SINGLE & DUAL MODE AND RIDGE WAVEGUIDE
  - DIELECTRIC OR METALLIC LOADED RESONATORS
- BAND STOP FILTERS

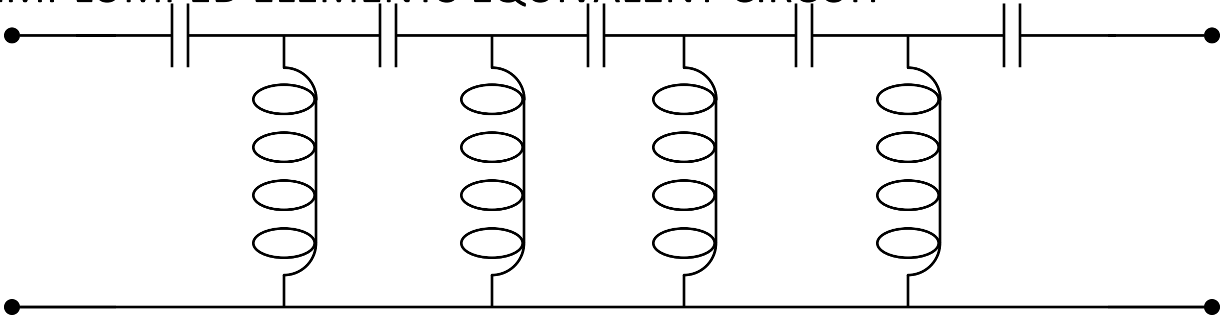
LOW PASS COAXIAL FILTERS



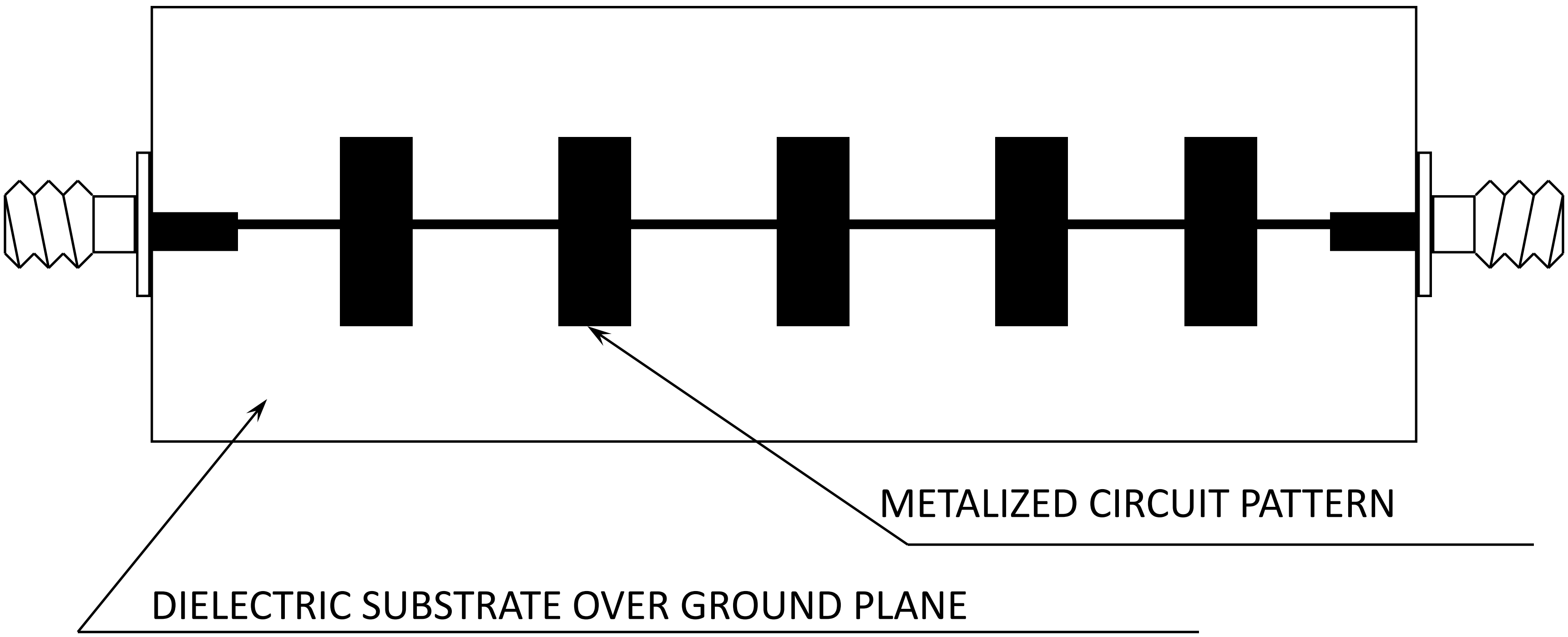
HIGH PASS COAXIAL FILTERS



SEMI-LUMPED ELEMENTS EQUIVALENT CIRCUIT

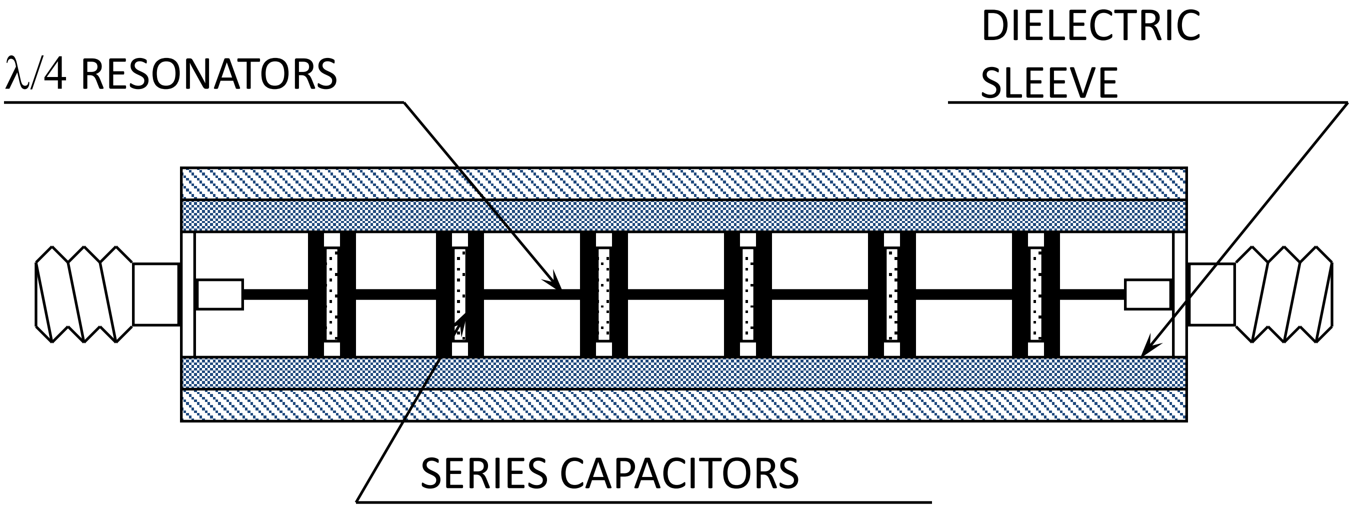


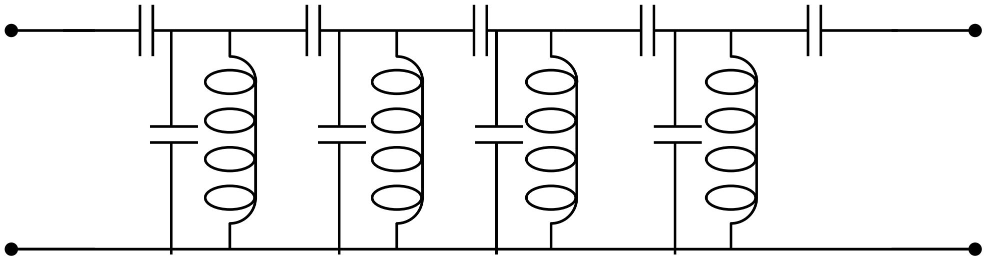
MICROSTRIP LOW PASS FILTERS



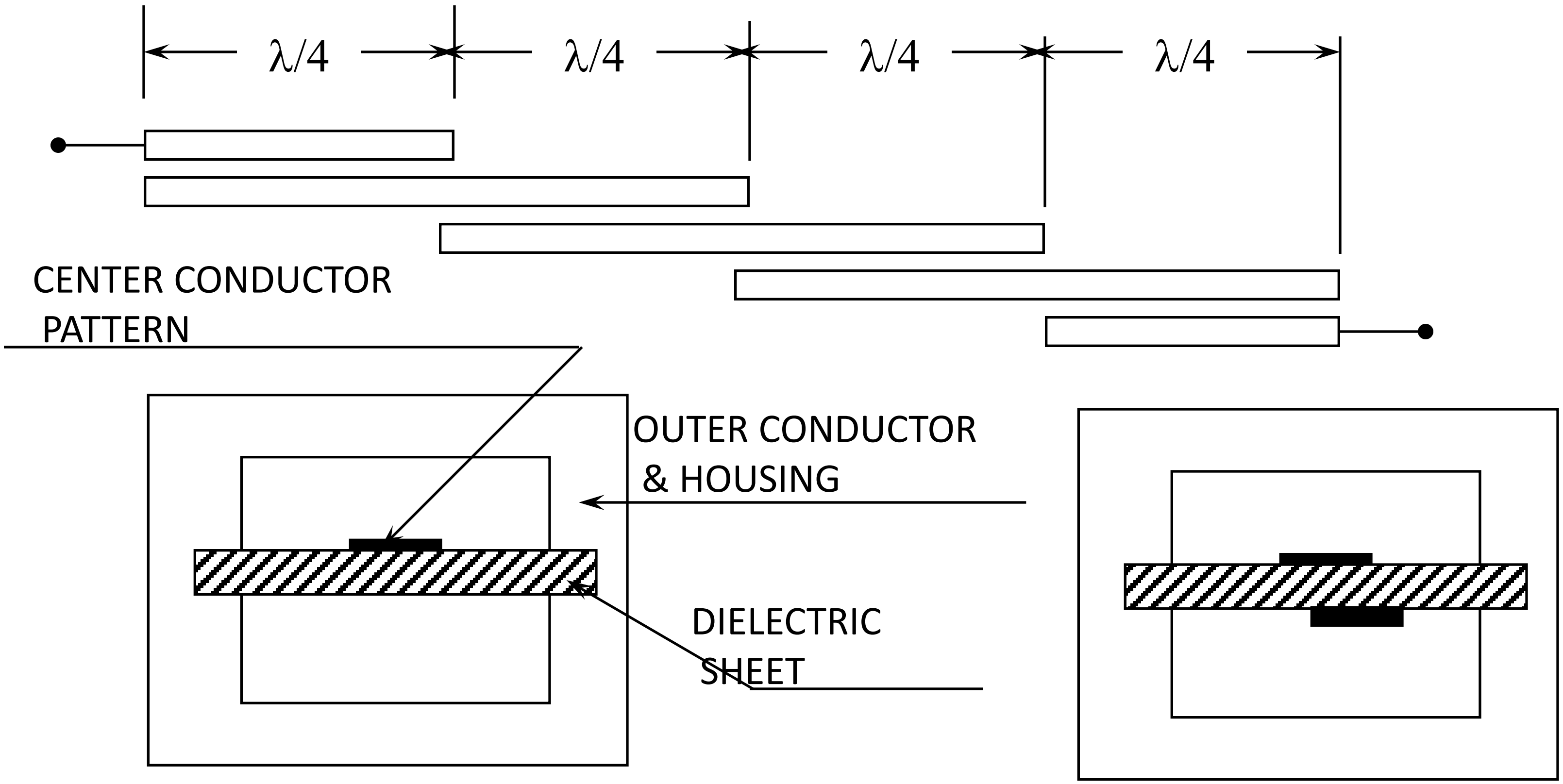
BAND PASS COAXIAL FILTERS

'DUMBELL' BANDPASS COAXIAL FILTER





PARALLEL COUPLED LINES

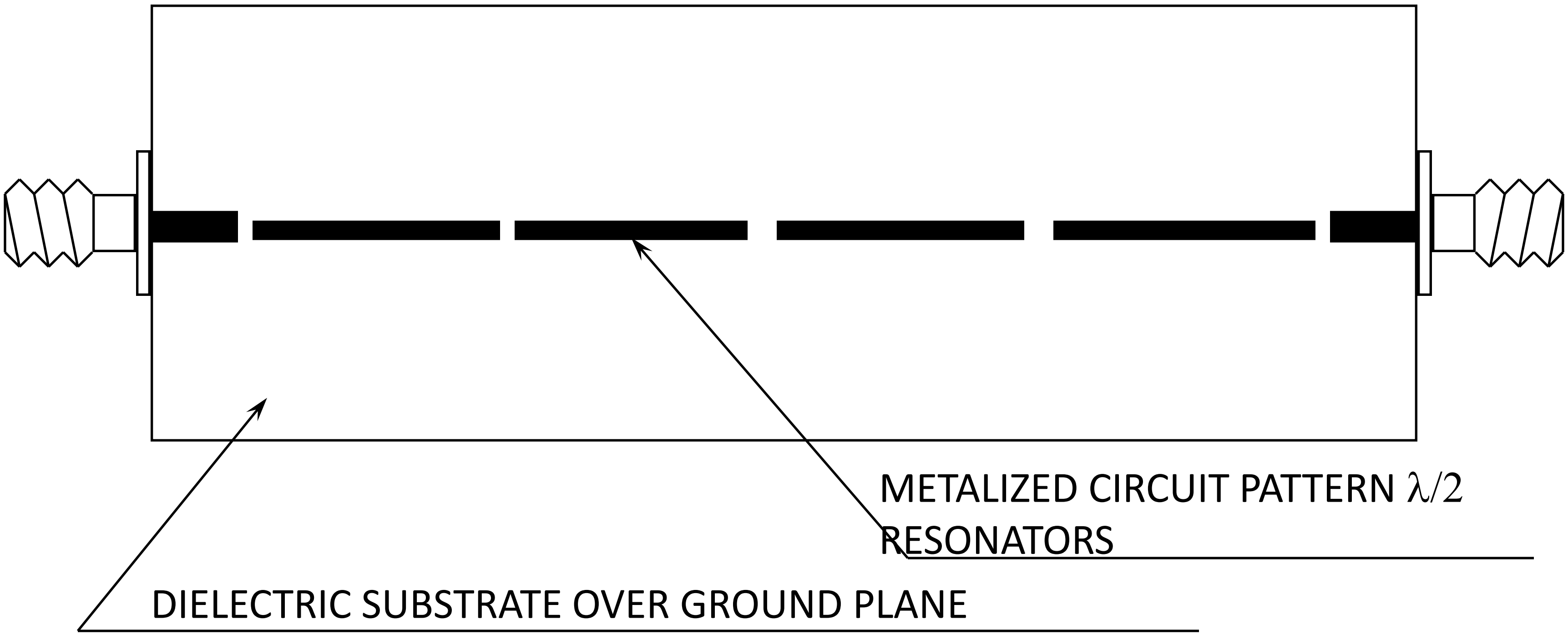


SUSPENDED SUBSTRATE LINE

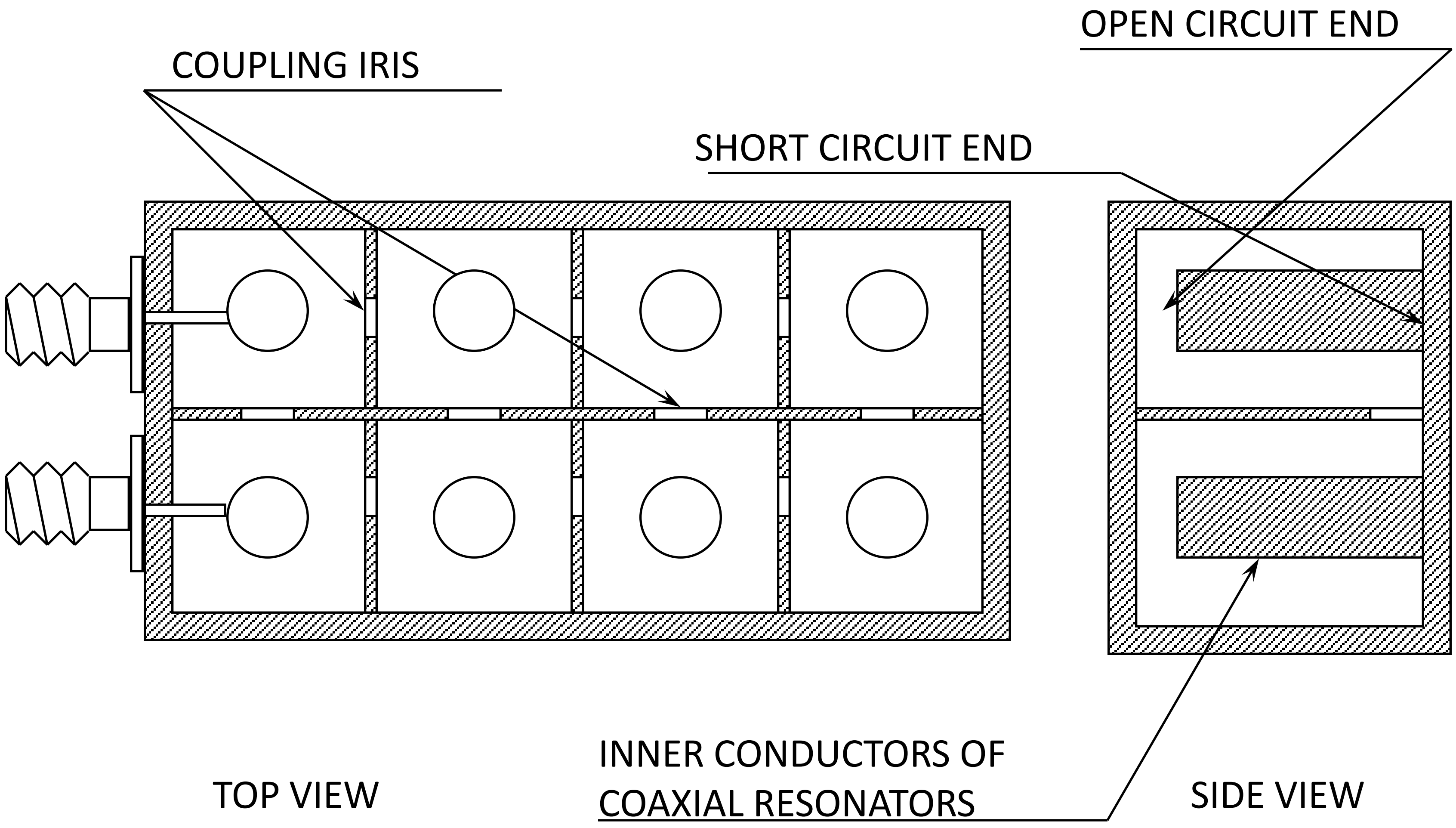
OVERLAY COUPLED LINES

- MICROSTRIP PRINTED CIRCUIT REALIZATION
- RECTANGULAR COUPLED BARS FOR WIDER BANDWIDTHE & HIGHER Q'S
- POSSIBLE SUSPENDED SUBSTRATE REALIZATION (HIGHER Q)

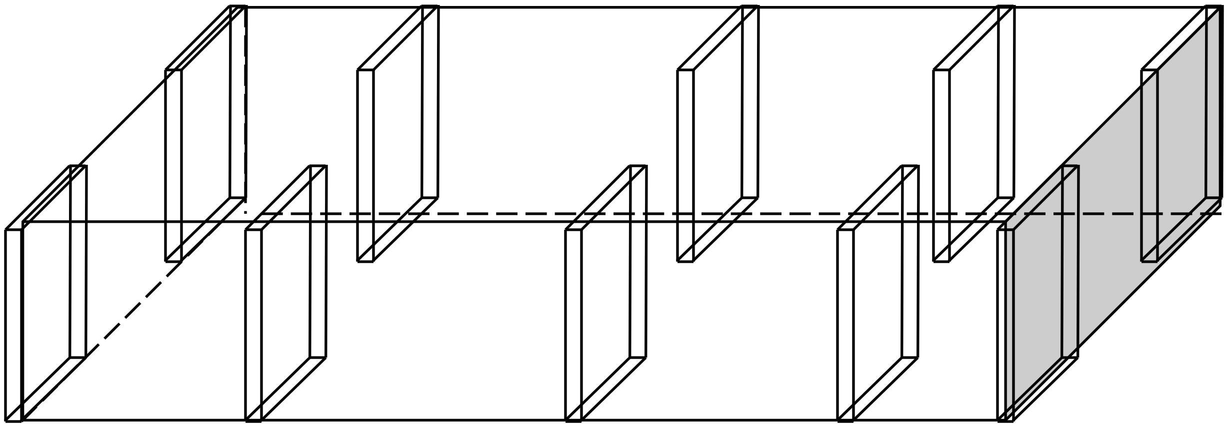
BANDPASS END COUPLED MICROSTRIP FILTERS



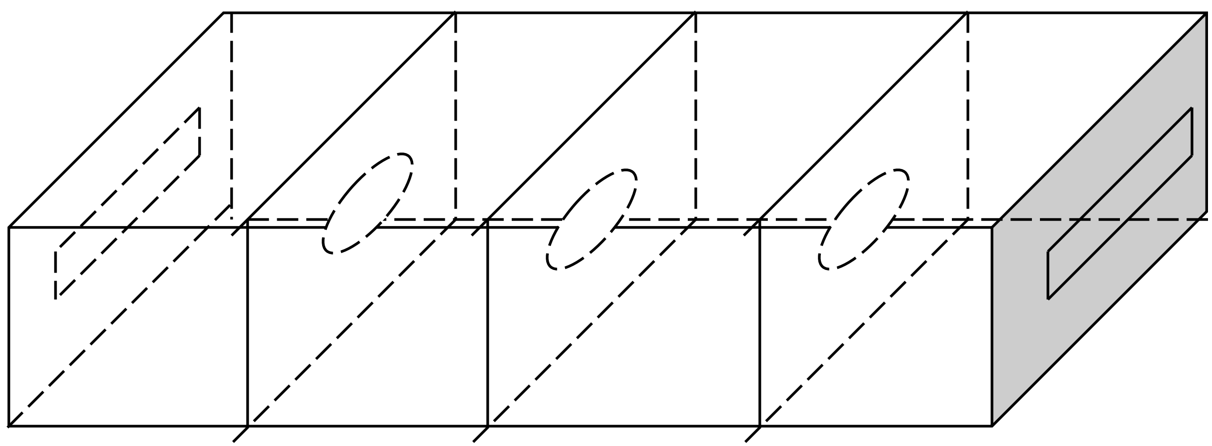
INTERDIGITAL & COMBLINE BAND PASS FILTERS



WAVEGUIDE FILTERS



INDUCTIVE WINDOWS (MODERATE BANDWIDTHS)



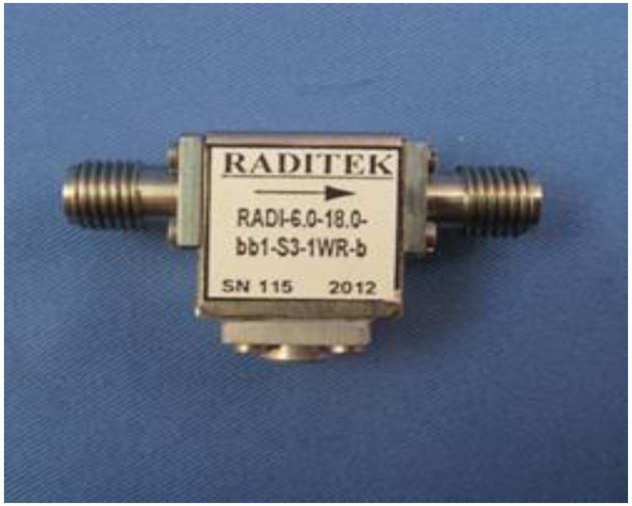
DIRECT COUPLED USING IRIS (NARROW BANDWIDTHS)

Cavity Filters
Waveguide
Filters
Lumped
Element
Tubular
Filters
Suspended
Substrate
SAW Filters
Rejected
Ceramic
Filters

Isolator and Circulator

- An RF isolator is a two-port ferromagnetic passive device which is used to protect other RF components from excessive signal reflection. Isolators are common place in laboratory applications to separate a device under test (DUT) from sensitive signal sources. An RF circulator is a three-port ferromagnetic passive device used to control the direction of signal flow in a circuit and is a very effective, low-cost alternative to expensive cavity duplexers in base station and in-building mesh networks.

Working



- To understand how these components control the signal flow, think of a cup of water into which you place a spoon and stir in a clockwise motion. If you sprinkle some pepper into the cup and continue to stir, you will notice that the pepper easily follows the circular motion of the water. You can also see that it would be impossible for the pepper to move in a counterclockwise direction because the water motion is just too strong. The interaction of the magnetic field to the ferrite material inside isolators and circulators creates magnetic fields similar to the water flow in the cup. The rotary field is very strong and will cause any RF/microwave signals in the frequency band of interest at one port to follow the magnetic flow to the adjacent port and not in the opposite direction.

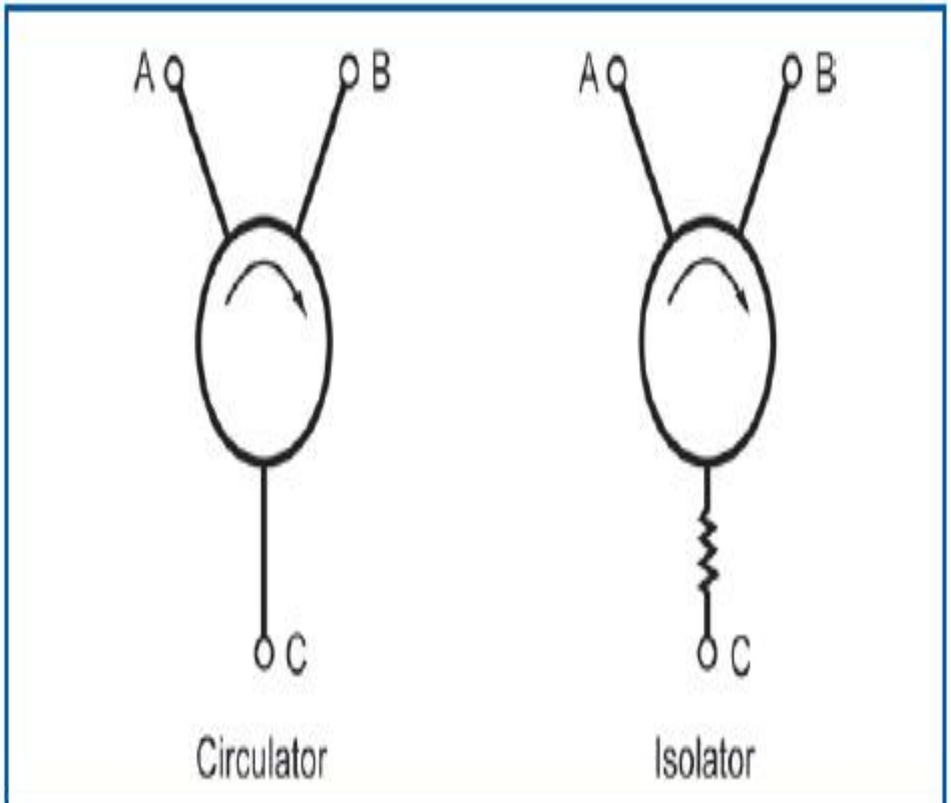


Figure 1

Figure 1 shows the schematics for a circulator and an isolator. Notice how an isolator is a circulator with the third port terminated. The arrows represent the direction of the magnetic fields and the signal when applied to any port of these devices. Example: if a signal is placed at port A, and port B is well matched, the signal will exit at port B with very little loss (typically 0.4dB). If there is a mismatch at port B, the reflected signal from port B will be directed to port C. As you will note, it makes no difference which port is the input of the circulator because the relationship at the outputs remains the same as these devices are electrically and mechanically symmetrical

- **Isolation**

An important consideration when specifying an isolator or circulator is to ensure the device has adequate isolation for your given application. Isolation is a unit of measure (in dB) that states the separation of signal levels on adjacent ports of a device. The greater the isolation value, the less interference from a signal on one port is present at the other. The amount of isolation is directly affected by the VSWR presented at port 3 of the isolator. If the match on port 3 is poor, you can expected isolation below 10 dB, but if the match is improved to 1.10:1 by using a good termination device in the circuit, then the isolation would improve to over 20 dB.

- **Insertion Loss**

  Another important consideration when specifying circulators and isolators is to ensure the device has minimal insertion loss when inserted in a transmission path. Generally, the insertion loss of a circulator/isolator (or any microwave device for that matter) becomes more significant at higher frequency, namely because loss increases with frequency and higher frequency power sources are considerably more expensive. Accordingly, the criteria of low insertion loss will prevent precious power from being wasted.

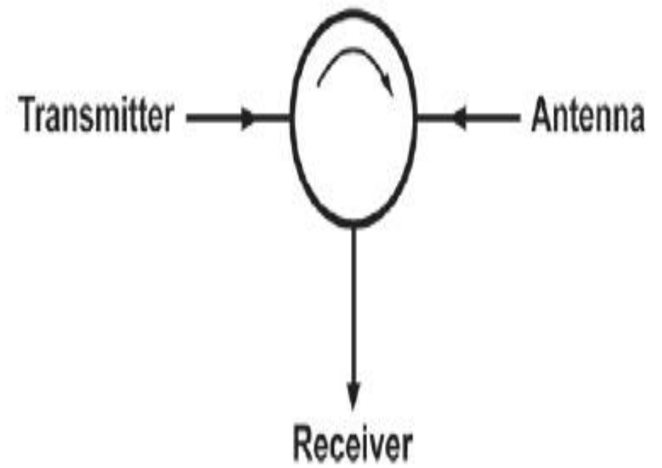


Figure 2: Duplexor

- **Common Applications**

  As described earlier, a common application for a circulator is as an inexpensive duplexer (a transmitter and receiver sharing one antenna). **Figure 2** shows that when the transmitter sends a signal, the output goes directly to the antenna port and is isolated from the receiver. Good isolation is key to ensure that a high-power transmitter output signal does not get back the receiver front end as is governed by the return loss of the antenna. In this configuration, all signals from the antenna go straight to the receiver and not the transmitter because of the circular signal flow (remember the cup of water).

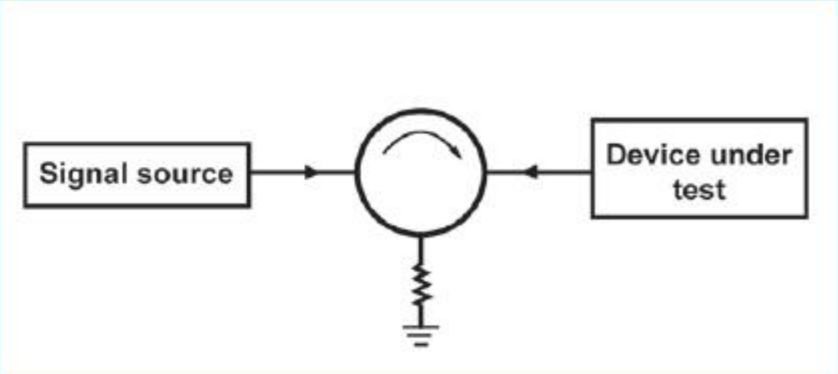


Figure 3

- **Figure 3** illustrates the most common application for an isolator. The isolator is placed in the measurement path of a test bench between a signal source and the device under test (DUT) so that any reflections caused by any mismatches will end up at the termination of the isolator and not back into the signal source. This example also clearly illustrates the need to be certain that the termination at the isolated port is sufficient to handle 100% of the reflected power should the DUT be disconnected while the signal source is at full power. If the termination is damaged due to excessive power levels, the reflected signals will be directed back to the receiver because of the circular signal flow.

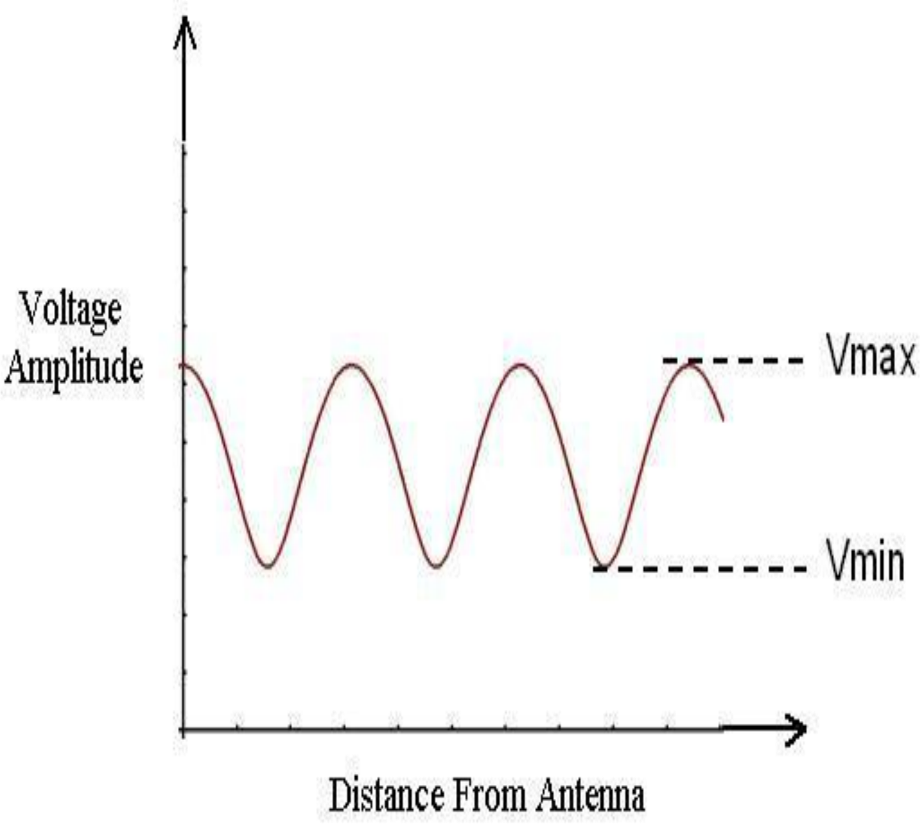
VSWR

- VSWR stands for **Voltage Standing Wave Ratio**, and is also referred to as Standing Wave Ratio (SWR). VSWR is a function of the reflection coefficient, which describes the power reflected from the antenna. If the reflection coefficient is given by Γ ,then the **VSWR** is defined by the following formula:

$$VSWR = \frac{1 + |\Gamma|}{1 - |\Gamma|}$$

- The VSWR is always a real and positive number for antennas. The smaller the VSWR is, the better the antenna is matched to the transmission line and the more power is delivered to the antenna. The minimum VSWR is 1.0. In this case, no power is reflected from the antenna, which is ideal.

- **Physical Meaning of VSWR**
- VSWR is determined from the voltage measured along a transmission line leading to an antenna. VSWR is the ratio of the peak amplitude of a standing wave to the minimum amplitude of a standing wave, as seen in the following Figure:



VSWR, Reflected Power, and Γ (s11)

VSWR	Γ (s11)	Reflected Power (%)	Reflected Power (dB)
1.0	0.000	0.00	-Infinity
1.5	0.200	4.0	-14.0
2.0	0.333	11.1	-9.55
2.5	0.429	18.4	-7.36
3.0	0.500	25.0	-6.00
3.5	0.556	30.9	-5.10
4.0	0.600	36.0	-4.44
5.0	0.667	44.0	-3.52
6.0	0.714	51.0	-2.92
7.0	0.750	56.3	-2.50
8.0	0.778	60.5	-2.18
9.0	0.800	64.0	-1.94
10.0	0.818	66.9	-1.74
15.0	0.875	76.6	-1.16
20.0	0.905	81.9	-0.87
50.0	0.961	92.3	-0.35

Electrical impedance Z

- **Electrical impedance** is the measure of the opposition that a circuit presents to a current when a voltage is applied.
- In quantitative terms, it is the complex ratio of the voltage to the current in an alternating current (AC) circuit. Impedance extends the concept of resistance to AC circuits, and possesses both magnitude and phase, unlike resistance, which has only magnitude. When a circuit is driven with direct current (DC), there is no distinction between impedance and resistance; the latter can be thought of as impedance with zerophase angle.

- Impedance is defined as the frequency domain ratio of the voltage to the current. In other words, it is the voltage–current ratio for a single complex exponential at a particular frequency ω. In general, impedance will be a complex number, with the same units as resistance, for which the SI unit is the ohm (Ω). For a sinusoidal current or voltage input, the polar form of the complex impedance relates the amplitude and phase of the voltage and current. In particular,
- The magnitude of the complex impedance is the ratio of the voltage amplitude to the current amplitude.
- The phase of the complex impedance is the phase shift by which the current lags the voltage.

- Microwave Capacitors - Are used as tuning elements, or as components in simple or complex filter structures.
- Microwave Resistors - Axial-leaded resistors, the ones with the color coded rings that you might be familiar with from misspent youth of busting stuff to "see how it works", are not going to work at microwave frequencies. This is because you have to consider that anything with dimensions longer than perhaps a sixteenth wavelength acts as distributed element. It is desirable for a resistor to behave like a lumped element in most microwave applications.

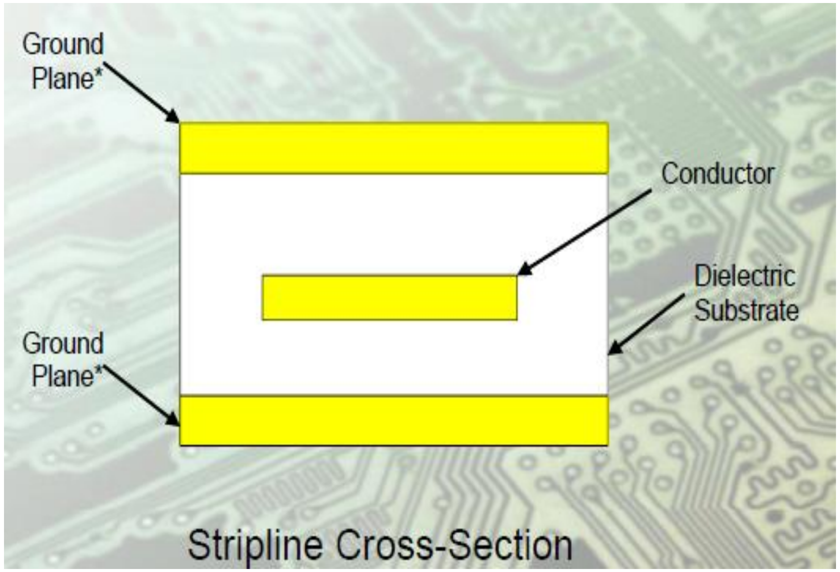
- Passive Device - contains no source that could add energy to your signal
- Power Divider–They couple a defined amount of the electromagnetic power in a transmission line to a port enabling the signal to be used in another circuit.
- Antenna - An electrical device which converts electric currents into radio waves, and vice versa. It is usually used with a radio transmitter or radio receiver.
- Phased Array - An antenna array is a group of multiple active antennas coupled to a common source or load to produce a directive radiation pattern. Usually, the spatial relationship of the individual antennas also contributes to the directivity of the antenna array.

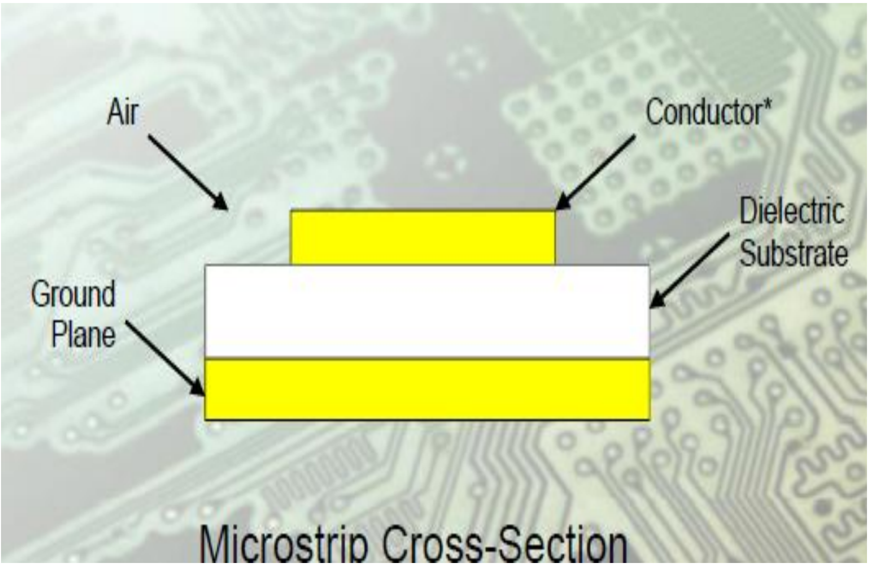
- Transmission Line - any pair of conductors used to move energy from point A to point B. The size is usually controlled and in a dielectric to create a controlled impedance.
- Frequency – the number of occurrences of a repeating event per unit of time. (Radio Frequencies are oscillations in the range of 30 kHz to 300 GHz.)
- Coaxial - A transmission line in which one conductor completely surrounds the other, the two being coaxial and separated by a continuous dielectric such as air or PTFE.
- Impedance - Resistance to alternating current. Most RF and microwave systems are designed to operate with a characteristic impedance of 50 ohms.

- Why 50 Ohms?
  - The standardization of fifty ohm impedance goes back to developing coax cables for kilowatt radio transmitters in the 1930s. The quick answer is that 50 ohms is a great compromise between power handling and low loss, for air-dielectric coax.

Band name	Abbr	ITU band	Frequency and wavelength in air	Example uses
sub-hertz	subHz	0	< 3 Hz > 100,000 km	Natural and man-made electromagnetic waves (millihertz, microhertz, nanohertz) from earth, ionosphere, sun, planets, etc[citation needed]
Extremely low frequency	ELF	1	3–30 Hz 100,000 km – 10,000 km	Communication with submarines
Super low frequency	SLF	2	30–300 Hz 10,000 km – 1000 km	Communication with submarines
Ultra low frequency	ULF	3	300–3000 Hz 1000 km – 100 km	Communication within mines
Very low frequency	VLF	4	3–30 kHz 100 km – 10 km	Submarine communication, avalanche beacons, wireless heart rate monitors, geophysics
Low frequency	LF	5	30–300 kHz 10 km – 1 km	Navigation, time signals, AM longwave broadcasting, RFID
Medium frequency	MF	6	300–3000 kHz 1 km – 100 m	AM (medium-wave) broadcasts
High frequency	HF	7	3–30 MHz 100 m – 10 m	Shortwave broadcasts, amateur radio and over-the-horizon aviation communications, RFID
Very high frequency	VHF	8	30–300 MHz 10 m – 1 m	FM, television broadcasts and line-of-sight ground-to-aircraft and aircraft-to-aircraft communications. Land Mobile and Maritime Mobile communications
Ultra high frequency	UHF	9	300–3000 MHz 1 m – 100 mm	Television broadcasts, microwave ovens, mobile phones, wireless LAN, Bluetooth, GPS and two-way radios such as Land Mobile, FRS and GMRS radios
Super high frequency	SHF	10	3–30 GHz 100 mm – 10 mm	Microwave devices, wireless LAN, most modern radars, communications satellites
Extremely high frequency	EHF	11	30–300 GHz 10 mm – 1 mm	Radio astronomy, high-frequency microwave radio relay, microwave remote sensing
Terahertz	THz	12	300–3,000 GHz 1 mm – 100 µm	Terahertz imaging – a potential replacement for X-rays in some medical applications, ultrafast molecular dynamics, condensed-matter physics, terahertz time-domain spectroscopy, terahertz computing/communications, sub-mm remote sensing

- **Stripline Circuit**
  - Stripline is a conductor sandwiched by dielectric between a pair of ground planes
  - The insulating material of the substrate forms a dielectric.
  - The width of the strip, the thickness of the substrate and the relative permittivity of the substrate determine the characteristic impedance of the strip which is a transmission line.
- **Microstrip Circuit**
  - A microstrip circuit uses a thin flat conductor that runs parallel to the ground plane.
  - Microstrip can be made by having a strip of copper on one side of a PCB or ceramic substrate while the other side is a continuous ground plane.
  - The width of the strip, the thickness of the insulating layer (PCB or ceramic) and the dielectric constant of the insulating layer determine the characteristic impedance.
  - Microstrip is by far the most popular


Ground Plane*
Conductor
Dielectric Substrate
Ground Plane*
Stripline Cross-Section


Air
Conductor*
Dielectric Substrate
Ground Plane
Microstrip Cross-Section

Limiters

- Radio and radar receivers must be capable of processing very small signals, necessitating the use of very sensitive circuit blocks that can contain fragile semiconductors. Many of these systems must also be capable of surviving very large incident signals, without damage to the sensitive components they contain. The receiver protection limiter, most often referred to simply as a limiter, can protect the receiver from large input signals and also allow the receiver to function normally when these large signals are not present

- Limiters are most often employed in radar transceivers, whose transmitters and receivers are tuned to the same frequency. The transmitter produces a signal, the peak level of which is in most systems in the kilowatts or megawatts order of magnitude, which is applied to an antenna that is typically also utilized by the receiver. The receiver must be capable of reliably detecting and processing very weak reflected signals, so it has a sensitive, low noise amplifier (LNA) at its input, although some receivers apply the received signal directly to the input of a down converter mixer. Both of these circuit blocks employ sensitive semiconductor components that will very likely be damaged by even a small portion of the transmitter signal that might be coupled to the receiver input, either by reflection from the antenna or by other means. A limiter can protect these components.

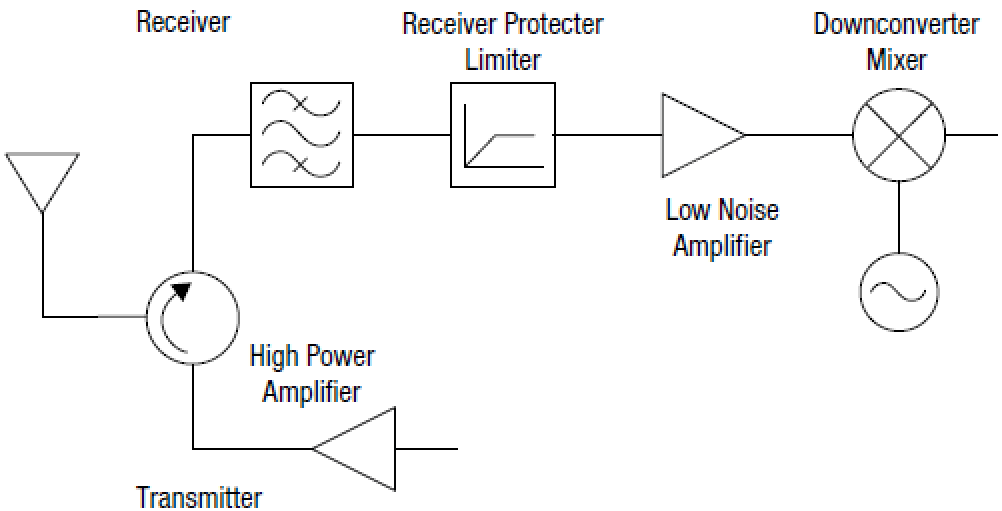


Figure 1. Simplified Radar Transceiver with a Receiver Protector Limiter

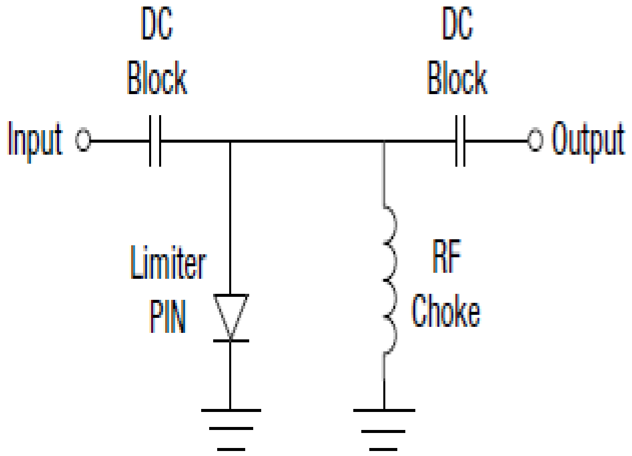


Figure 2. A Single-Stage Limiter

LNA : Low Noise Amplifier

- Introduction
  - Some applications require receivers to maintain extraordinarily low noise figure (NF). In these cases, it is possible to use an external low-noise amplifier (LNA) to improve the cascaded NF.
- Why Use an LNA?
  - An LNA is typically used to provide low noise gain as close as possible to the antenna. Sometimes, especially in GPS receiver applications, the LNA is integrated into an active antenna. The ultimate effect is a reduction in receiver's noise figure achieved by amplifying the desired signal before it is attenuated by other, passive components in the receiver chain.

- A phase-locked loop is a feedback system combining a voltage controlled oscillator (VCO) and a phase comparator so connected that the oscillator maintains a constant phase angle relative to a reference signal. Phase-locked loops can be used, for example, to generate stable output high frequency signals from a fixed low-frequency signal.

Power Amplifiers

- Common-emitter amplifiers and operational amplifiers require high impedance loads.
- To drive low impedance loads, a power output stage is required.
- Designs vary in complexity, linearity and efficiency.
- Power dissipation and thermal effects must be considered.

Differences between power amplifier designs :

- Efficiency / Power dissipation.
- Complexity / Cost.
- Linearity / Distortion.

Properties of Power Amplifier Stage :

☑ Low voltage gain (usually unity).

☑ High current gain.

☑ Low output impedance.

☑ High input impedance.

Power amplifier designs are usually classified according to their *conduction angle*.

Conduction Angle

The conduction angle gives the proportion of an a.c. cycle which the output devices conduct for.

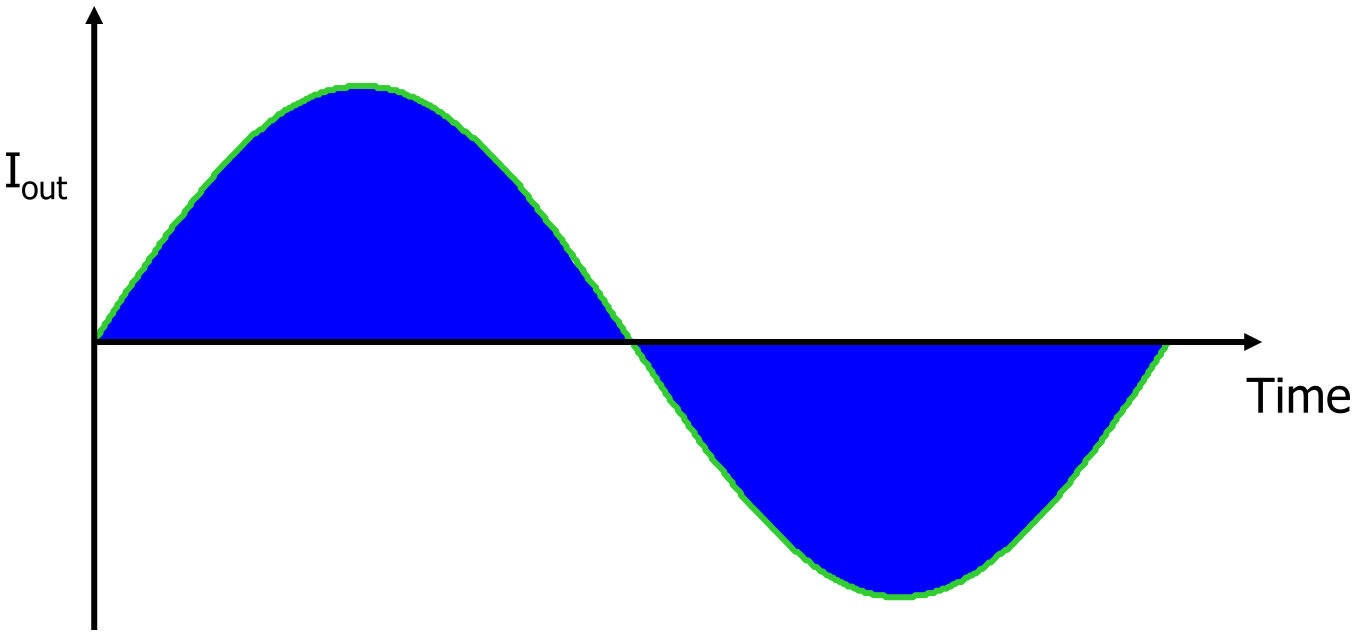
E.g.

On all the time $\Rightarrow$ 360 °

On half the time $\Rightarrow$ 180 °

etc.

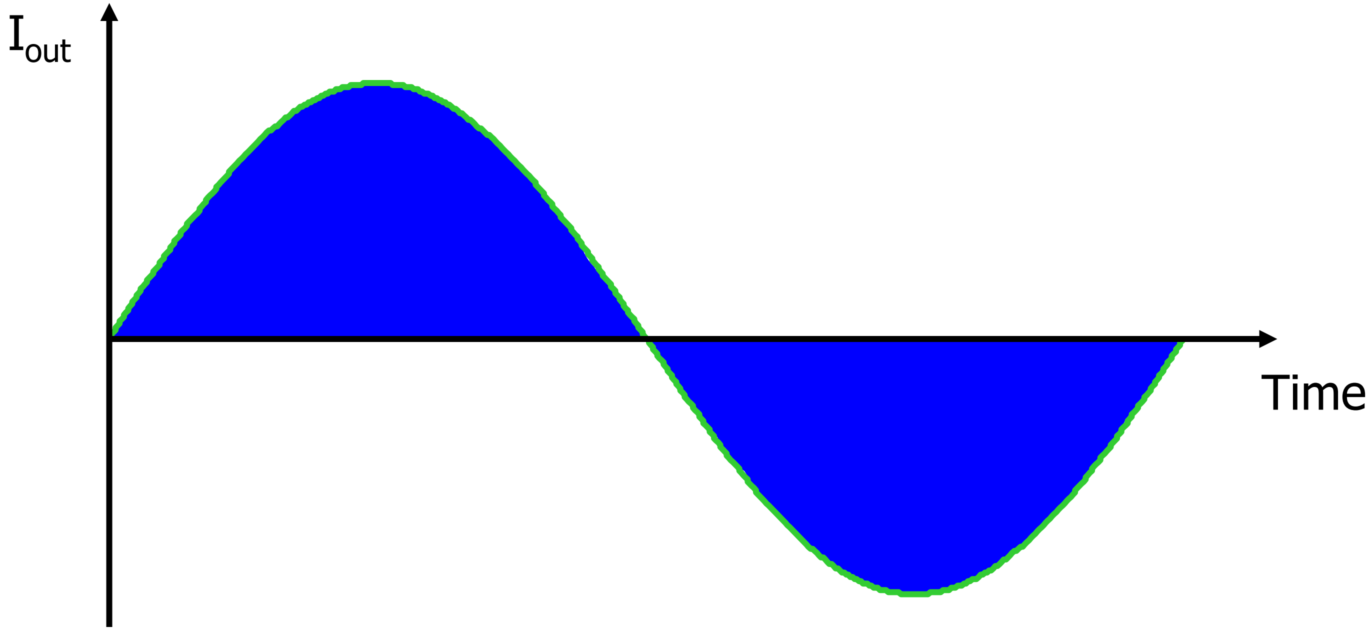
Class A Operating Mode



One device conducts for the whole of the a.c. cycle.
Conduction angle = 360 °.

The Class A stage must be biased at a current greater than the amplitude of the signal current.

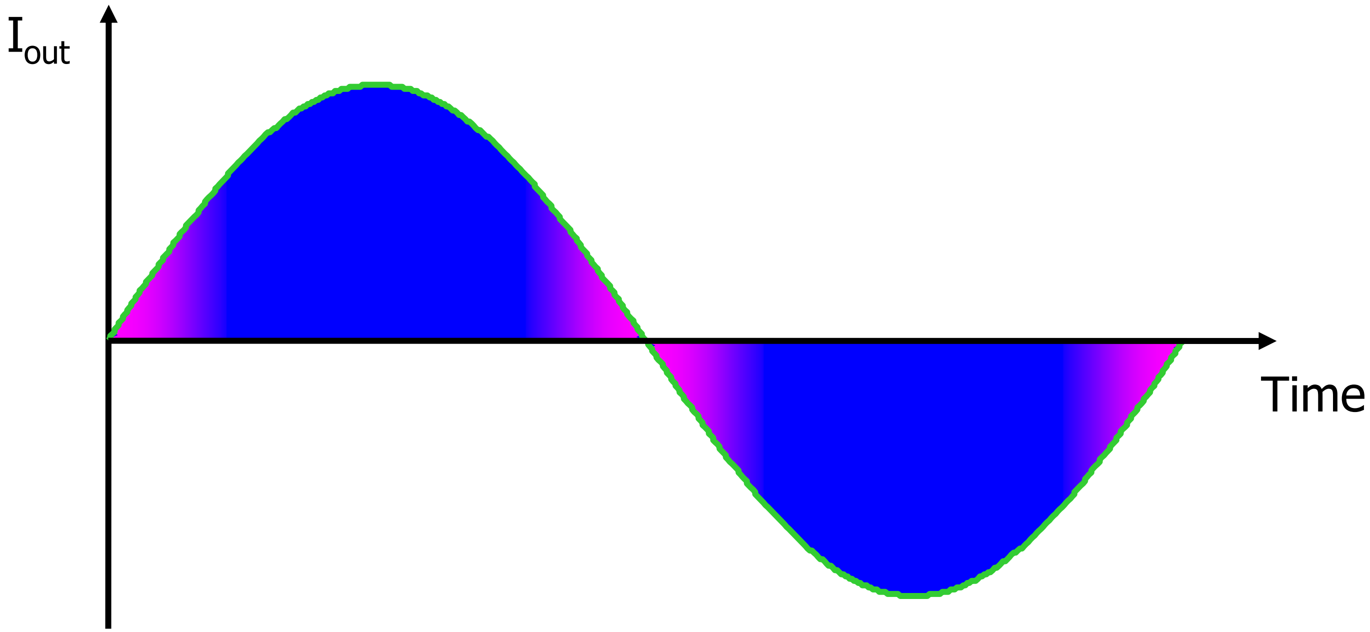
Class B Operating Mode



Two devices, each conducting for half of the a.c. cycle.

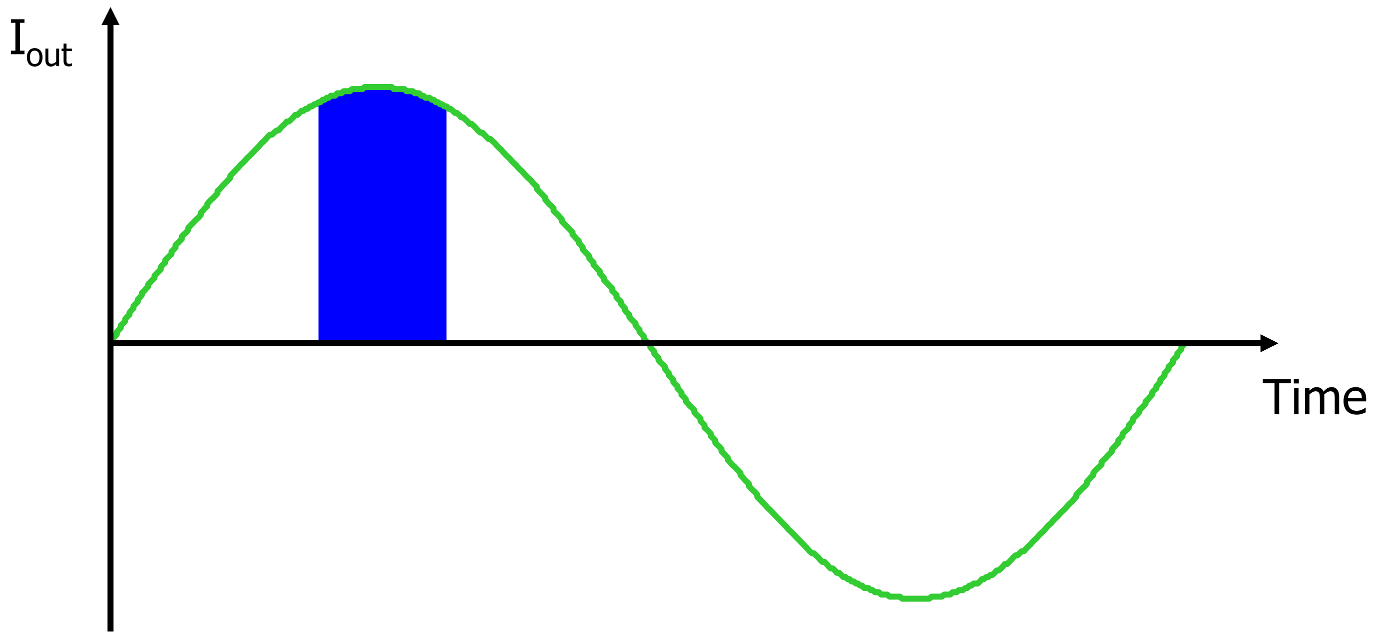
Conduction angle = 180 °.

Class AB Operating Mode



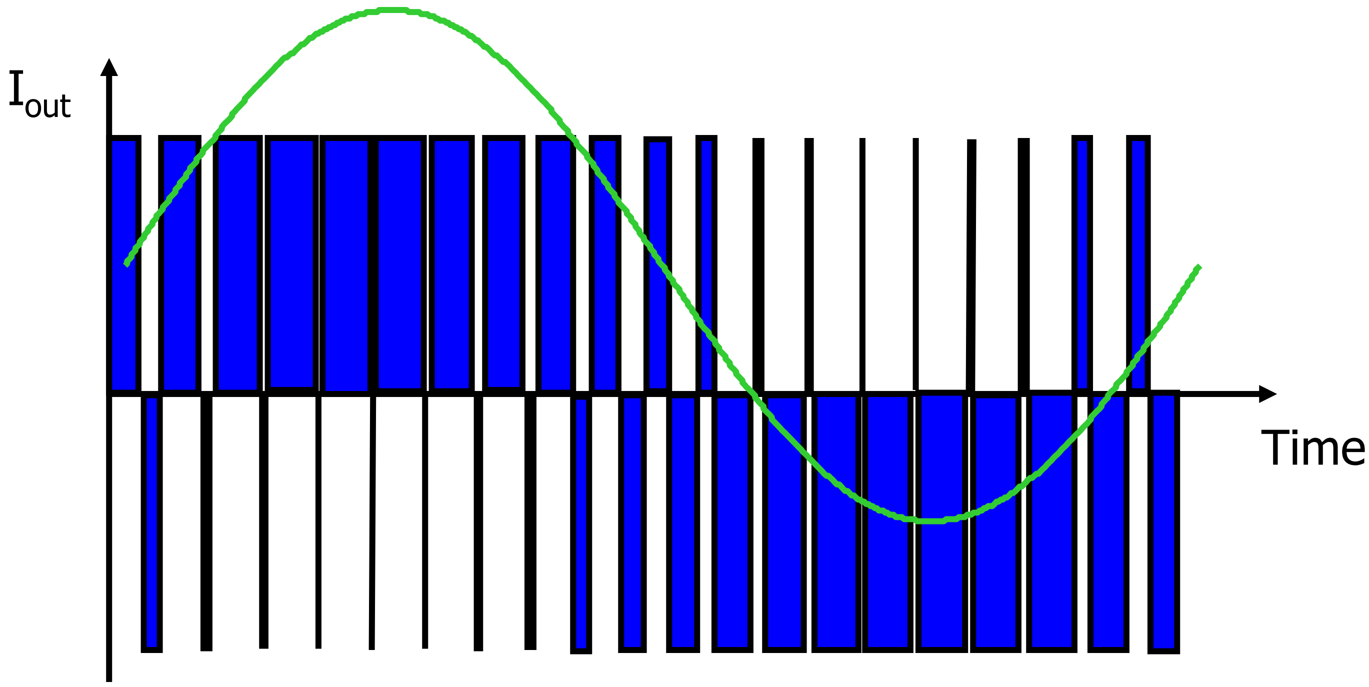
Two devices, each conducting for just over
half of the a.c. cycle.
Conduction angle > 180 ° but << 360 ° .

Class C Operating Mode



One device conducts a small portion of the a.c. cycle.
Conduction angle << 180 °.

Class D Operating Mode

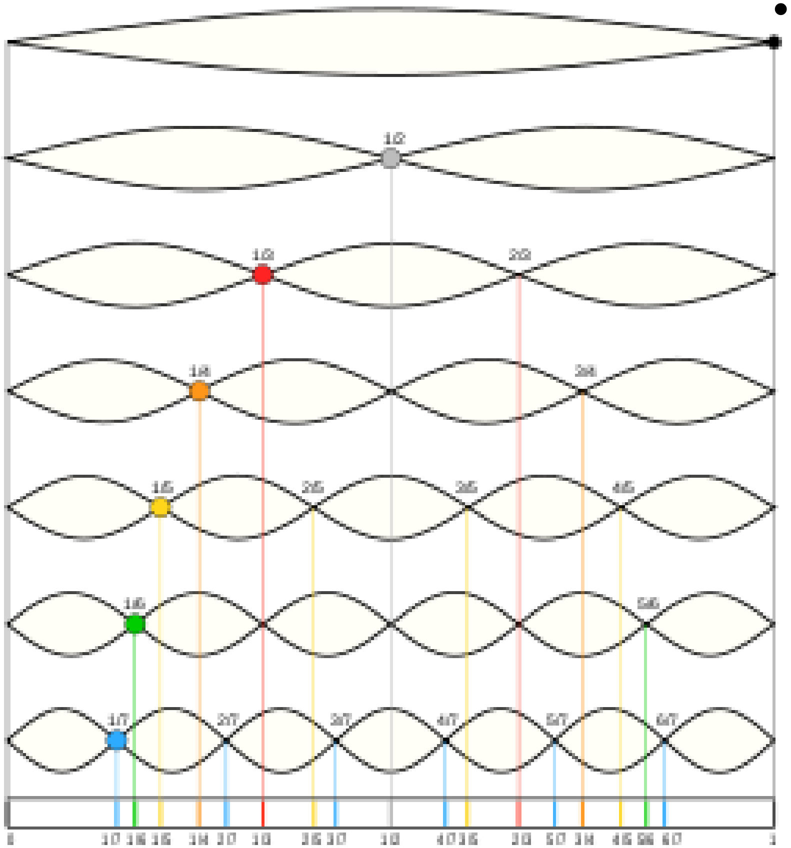


Each output device always either fully on or off – theoretically zero power dissipation.
Example: The built-in speaker in a PC is driven by a Class D type "on/off' circuit.

- **Noise figure** (NF) and **noise factor** (*F*) are measures of degradation of the signal-to-noise ratio (SNR), caused by components in a radio frequency (RF) signal chain. It is a number by which the performance of an amplifier or a radio receiver can be specified, with lower values indicating better performance.
- The noise factor is defined as the ratio of the output noise power of a device to the portion thereof attributable to thermal noise in the input termination at standard noise temperature T_0 (usually 290 K). The noise factor is thus the ratio of actual output noise to that which would remain if the device itself did not introduce noise, or the ratio of input SNR to output SNR.
- The noise *figure* is simply the noise *factor* expressed in decibels (dB).

- **Signal-to-noise ratio** (often abbreviated **SNR** or **S/N**) is a measure used in science and engineering that compares the level of a desired signal to the level of background noise. It is defined as the ratio of signal power to the noise power, often expressed in decibels. A ratio higher than 1:1 (greater than 0 dB) indicates more signal than noise.

Harmonics



- A **harmonic** of a wave is a component frequency of the signal that is an integer multiple of the fundamental frequency, i.e. if the fundamental frequency is *f*, the harmonics have frequencies 2*f*, 3*f*, 4*f*, . . . etc. The harmonics have the property that they are all periodic at the fundamental frequency, therefore the sum of harmonics is also periodic at that frequency. Harmonic frequencies are equally spaced by the width of the fundamental frequency and can be found by repeatedly adding that frequency. For example, if the fundamental frequency (first harmonic) is 25 Hz, the frequencies of the next harmonics are: 50 Hz (2nd harmonic), 75 Hz (3rd harmonic), 100 Hz (4th harmonic) etc.
-

Spurious Emission

- A **spurious emission** is any radio frequency not deliberately created or transmitted, especially in a device which normally does create other frequencies. A harmonic or other signal outside a transmitter's assigned channel would be considered a spurious emission.

Thank You