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UHF MILITARY EQUIPMENT
CHAPTER ONE
UHF CHARACTERISTICS

1.0 USE OF UHF FOR SHORT-RANGE COMMUNICATIONS

The ultra high frequency band is being used more and more for short-range communications. Some of the advantages in using UHF for this service are:

(1) More frequency channels are available in this band. The lower frequency bands are very crowded as far as utilization is concerned, and must be reserved for long-range communications, for which the lower frequencies are so well suited.

(2) Line-of-sight propagation at ultra high frequencies reduces the possibility of interference between stations and permits many stations to use the same frequency, provided they are separated by a few hundred miles.

(3) Very little atmospheric noise is encountered at the ultra high frequencies. This is of utmost importance since lower frequencies are seriously affected and may be made useless by storms or other atmospheric disturbances. The absence of atmospheric noise permits rather simple carrier-operated "squelch" circuits to be used in the receivers. These "squelch" circuits silence the receiver except when signals are actually being received, thus reducing operator fatigue.

(4) Antennas can be made smaller and simpler in structure, both on the aircraft and at ground stations. Also, good directional characteristics can be obtained for point-to point type communications.

2.0 CHARACTERISTICS OF UHF PROPAGATION

UHF and VHF radio waves differ from lower frequency waves in that they are not reflected by the ionosphere, except under unusual circumstances. The ionosphere is a region from about ~~30~~ 150 to 250 miles above the earth's surface which is composed of several layers of charged or ionized particles. This ionized layer of air tends to bend the radio waves back to the earth.

This reflecting phenomenon makes possible long-range communication at frequencies from about 3 to 30 megacycles. Since UHF waves are not returned to the earth by the ionosphere, their transmission is normally limited to distances which are slightly greater than the optical line of sight. The lower atmosphere tends to bend radio waves downward so that they will travel slightly beyond the optical horizon. The mathematical expression for the radio line-of-sight distance is $D = \sqrt{2h} + \sqrt{2H}$, where D is the distance in statute miles, h is the height of one antenna and H is the height of the other antenna. This equation takes into consideration the bending by the lower atmosphere which is known as refraction. (h & H are in feet.)

Because the earth tends to reflect radio waves, it is possible to obtain interference at the receiving point between the direct wave from the transmitting antenna and the reflected wave. Although this type of interference, known as "lobing", can cause loss of signal strength under certain conditions, the effects are not serious with adequate transmitter power and receiver sensitivity.

3.0 OPERATION OF VACUUM TUBES IN UHF CIRCUITS

3.1 Electron Transit Time

In low frequency operation it is usually taken for granted that electrons leaving the cathode reach the plate instantaneously. No harm is done by this assumption, so long as the actual time of flight of electrons between the cathode and the plate is negligible compared to the duration of one cycle. If the total transit time is less than one-tenth of a cycle, the tube operates satisfactorily. At times longer than one-tenth cycle, the efficiency drops considerably. In the operation of vacuum tubes in UHF circuits, electron transit time must be considered. The undesirable effects of electron transit time, which cause the efficiency to drop, are heating of the plate, heating of the cathode, and grid circuit loading.

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from cat to pl

Plate heating is caused by electron bombardment of the plate. At low frequencies maximum electron flow occurs when the plate voltage is minimum and the grid voltage at its maximum positive value. This large electron flow is caused by the positive grid. At ultra high frequencies, all of these electrons do not have time to reach the plate before the plate voltage starts rising. This rising plate voltage accelerates the electrons toward the plate, which in turn bombard the plate.

Cathode heating is caused by electron bombardment of the cathode. The large number of electrons that left the cathode under the influence of the positive grid, do not have time to pass through the grid before the grid goes negative. The negative grid forces the electrons back toward the cathode causing them to bombard the cathode. This is referred to as "cathode back-heating". The filament voltage can be reduced so that the total heating of the cathode by the heater and by electron bombardment is normal for the tube.

Grid circuit loading is caused by an uneven distribution of electrons on each side of the grid. This uneven distribution is a result of the electron transit time and causes a voltage to be induced on the grid. The induced voltage causes current to flow in the grid circuit, which has the effect of lowering the input impedance of the tube. The lower input impedance reduces the input signal voltage.

Electron transit time can be decreased by reducing the spacing between the elements of the tube and by increasing the plate voltage.

3.2 Operation of Triodes

At higher radio frequencies, interelectrode capacities, lead inductances, and electron transit time limit the useful operation of triodes. The operation becomes unstable and the efficiency drops. The operation of neutralized triodes becomes unstable above about 30 megacycles and the frequency range over which neutralization is satisfactory is narrow. Operation of triodes as grounded-grid amplifiers will improve stability since they do not have to be neutralized. The type 6J4 tube is an example of a triode designed for grounded-grid operation at frequencies up through 400 megacycles.

3.3 Operation of Tetrodes

In the tetrodes electron transit time is reduced by the high accelerating effect of the screen grid. The grid-plate capacity is low and neutralization is not required at the lower frequencies. At higher frequencies, neutralization is required, but is simpler to obtain. The lighthouse type of tetrode does not require neutralization.

4.0 RECEIVER NOISE

The useful sensitivity of any receiver is limited by noise. This noise is generated external to the receiver and also within the receiver. The external noise is usually not objectional at ultra high frequencies, therefore, the useful sensitivity of a UHF receiver is limited by the noise generated within the receiver, primarily in the first few stages where the signal is weak.

There are three types of noise generated within vacuum tubes, and all are important in UHF receivers. They are Shot-Effect Noise, Interception Noise, and Induced Grid Noise. Another type of noise is that generated in conductors and resistors by thermal agitation. Noise is random and varies directly ~~inversely~~ error with bandwidth, therefore the use of minimum bandwith improves performance. Interception noise and induced grid noise can be minimized by the use of special triodes. Thermal agitation noise can be reduced by use of grounded-grid amplifiers.

5.0 LOSSES IN UHF CIRCUITS

The losses in UHF circuits consist of losses due to skin effect, conductor losses, dielectric losses, radiation losses, and eddy current losses.

Skin effect is the term used to describe the concentration of current near the surface of a conductor. Skin effect increases when the frequency is increased. The loss from skin effect can be reduced by using conductors made of copper tubing or copper ribbons. caused by magnetic field build up arounda conductor

Conductor loss is the loss due to the resistance of the conductor and can be reduced by using conductors of low resistance.

Dielectric loss is the loss in dielectric materials. This loss increases when the frequency is increased and can be reduced by using dielectric materials with a low loss factor. The loss factor is the product of the dielectric constant and the power factor of the dielectric material.

Radiation loss is the loss due to undesired radiation from wiring and components. This loss increases when the frequency is increased and can be reduced by shielding and by arranging the wiring and components to cancel radiation.

Eddy current loss is the loss due to voltages being induced in metal components which cause currents to flow in the metal, thereby wasting power. This loss increases when the frequency is increased.

6.0 DISTRIBUTED EFFECTS IN UHF CIRCUITS

In UHF circuits the distributed capacitance and inductance is a large portion of the capacitance and inductance required in the tuned circuits. The reactance of the capacitance between the wiring and ground decreases as the frequency is increased. As a result more of the signal is bypassed to ground when the frequency is increased. The interelectrode capacities of vacuum tubes must also be considered since they may be a large portion of the capacitance required in the tuned circuits. Resistors have distributed inductance and capacitance. Inductors have distributed capacitance and capacitors have distritubed inductance.

To reduce distrubuted effects the circuits can be made smaller physically and closer together. Wiring should be as short as possible.

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