Mutual Interference–

Its Relation to Spectrum Conservation

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Radio equipments operating at the same time in the same vicinity although on different frequencies, often interfere seriously with one another. Such interference is termed "mutual" interference.

In the Winter 1957 issue of Collins Signal, Norman S. Hime, Research and Development Division, Collins Radio Company, Cedar Rapids, Iowa, writes on the mutual interference problem. He describes different kinds of interference and how their effects can be avoided or reduced by basic equipment design and properly planned installations.

His article, although shortened, is substantially as follows.

Recognition and understanding of the various mutual interference effects is needed to make the best use of the ever shrinking radiofrequency spectrum.

Some of today's difficulties come from not enough consideration of mutual interference effects before a facility is built. Many systems today can operate only because timewise they are not too heavily loaded with traffic.

As an illustration, recent experimental work has established that even in the relatively large UHF spectrum from 225 to 400 megacycles, it is impractical to operate even a dozen transmitter/receiver systems simultaneously at a typical site, regardless of frequency allocation, without serious problems of mutual interference and marked degradation of system performance.

On the brighter side, however, it has been shown that through the use of additional preselection, both before the receiver and after the transmitter, system performance can be improved to the point where essentially interference-free operation can be obtained with greatly reduced frequency spacings.

Percentage

A fair percentage of system operation difficulties are caused by insufficient consideration regarding certain basic performance requirements for the transmitters and receivers that make up the communication (or navigation) system.

Transmitter specifications, for example, normally provide for rigid restrictions on harmonic radiation, spurious radiation, and modulation splatter. These are important. However, there is a fourth category of undesired transmitter radiation—transmitter intermodulation. This effect is produced when two transmitters are operated with relatively little isolation between their antennas.

Interference products of relatively high levels (compared to receiver sensitivities) can be created not only in frequency ranges immediately adjacent to those of the particular transmitters producing the intermodulation products, but also in widely separated frequency regions (figure 1).

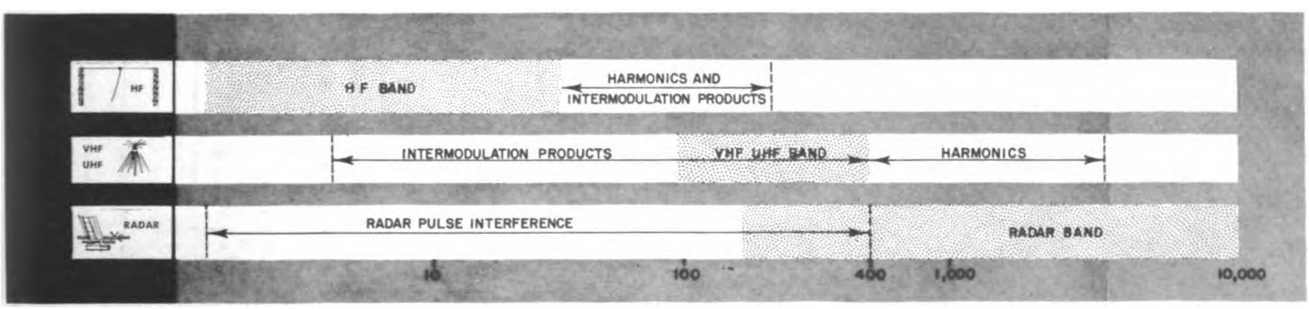
For example, the difference frequency between two UHF transmitters can easily occur in the HF ranges. Even the most perfect receiver is defenseless against interference that is on the frequency to which it is tuned. This type of interference can be directly reduced either by filtering or by using a linear output amplifier in the transmitter.

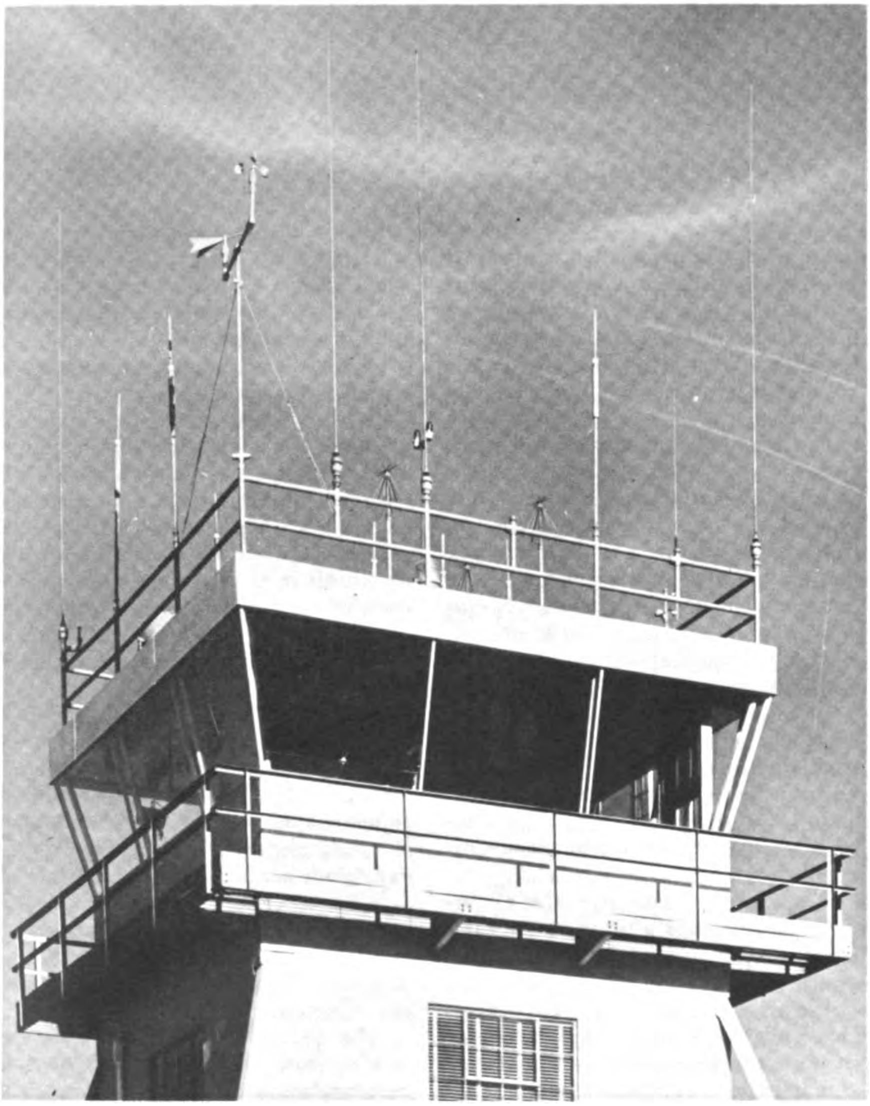
Adverse Effects

- There are even more adverse receiver effects than transmitter effects. The normal ones are spurious responses, image responses, IF feed through, susceptibility or back door sensitivity, and radiation.
- Other receiver effects that are not so well known are intermodulation, cross modulation, overload, desensitization, and radar pulse interference.

The modern superheterodyne receiver can deal with the normal effects rather well. However, for intermodulation, cross modulation, overload, and desensitization, particular care must be given to get adequate selectivity ahead of any stages where mixing may occur. Radar pulse interference resulting from detection in the receiver can

Figure 1. Graph of interference effects from transmitters. Frequency range of transmitters analyzed is keyed at the left of each bar.





generally be suppressed by noise limiter techniques.

To restate the situation, the normal problems can best be handled by design in the equipment itself. The system interference problems are best treated by additional filtering or specific design requirements related to the system problems.

Cost Saving

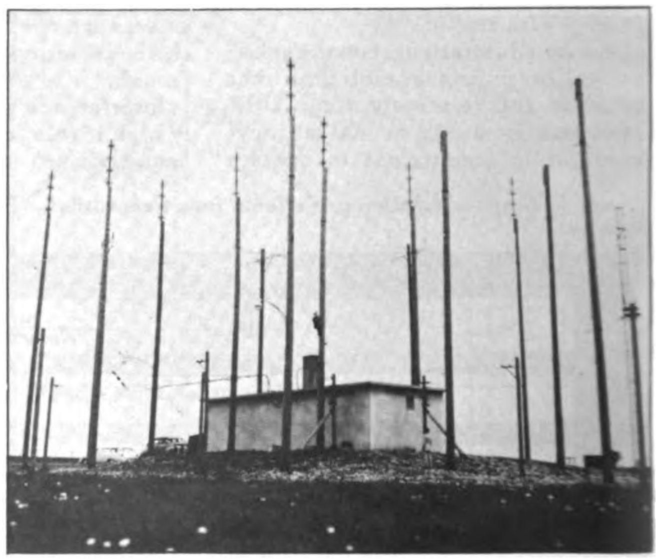
Experimental and analytical work has established that there can be a major cost saving through the use of interference reduction techniques. In the UHF region, for example, it is practical to combine receiver and transmitter installations in one place by using relatively inexpensive selective filters.

The use of a single site is valuable when an installation is to be made in difficult terrain where access is a problem. Also, one location eliminates the need for additional operators, and there are savings in antennas and towers.

Intermodulation

Transmitter intermodulation occurs when the output of one power amplifier couples into another and produces a difference output. The conventional Class C amplifiers are very efficient mixers. They function as such in the normal process of high-level modulation in which the audiofrequency volt-

The photographs on this page show radio concentration at air terminals, aboard ship, and at fixed stations.



age impressed on the power amplifier plate supply produces sidebands.

In the same manner, the output of a transmitter may also appear at the power amplifier plate of another to generate A − B, A + B output, plus various combinations of harmonics of one mixing with the fundamental of the other to produce the commonly known third order, or 2A − B type of product. The latter are particularly important in that they produce undesired radiation in the frequency spectrum in use. (Figure 2.)

For example, with 0 db isolation between the two transmitter power amplifiers, the third order products are only about 15 db below the carrier level. For a 100-watt transmitter, this would be the equivalent of a transmitter radiation of about 3 watts. In a normal installation about 50 db isolation is usually possible between power amplifiers at UHF without too much physical isolation.

However, even this arrangement results in a radiated signal level that is very high compared to the sensitivity of receivers that are in the same location.

Three things may be done to reduce the effects of transmitter intermodulation.

1. Pick frequency assignments such that the third and fifth order products do not fall on, or immediately adjacent to, desired receiver frequencies.

2. Use selective filters to provide additional selectivity (that is, isolation) between transmitters.

3. Use linear amplifier techniques to reduce the basic intermodulation product that is generated.

The latter two are the more practical solutions because they give greater flexibility in frequency assignments.

It is possible at UHF, for example, to obtain additional selectivity, while taking only a small loss in the effective power output of the transmitter. This insertion loss averages about 1.6 db.

Selective filters of simple mechanical design which are essentially tunable cavities tuned by a precision leadscrew, will furnish additional suppression to spurious outputs and harmonic radiation. Some of these filters have a Q of approximately 10,000 unloaded and 1,000 loaded which gives a further idea of their selectivity.

Cross Modulation

Receiver cross modulation is the modulating of the desired carrier by the modulation of an undesired carrier nearby. This phenomenon usually occurs in the early amplifier stages of the receiver and is the result of vacuum tube third-order action.

In receiver cross modulation the modulation of the undesired signal is heard when the desired carrier is present, but if the desired carrier is absent, the modulation of the undesired signal is no longer heard. This condition is the result of poor receiver RF selectivity, inadequate transmitter-receiver antenna isolation or too little frequency separation between desired and undesired signals.

Desensitization

Receiver desensitization occurs when receiver sensitivity is reduced due to the presence of high level off-channel signals causing overloading of the RF amplifier and mixer stages. This condition results from inadequate receiver preselection, insufficient isolation between transmitters and receivers, and insufficient frequency separation of desired and undesired signals.

Intermodulation

Receiver intermodulation interference is the production of an intermodulation product at a receiver response frequency. This intermodulation product is generated by two or more undesired signals mixing in the RF amplifier and mixer stages of the receiver.

This interference occurs as a result of nonlinear RF circuits in the receiver. It may be alleviated by increasing circuit linearity, RF preselection, and receiver-transmitter isolation.

Spurious Response

Receiver spurious responses are frequencies other than the desired frequency which may be converted to the intermediate frequency. The over-all frequency-pass characteristic of a receiver shows many frequencies that present a lower attenuation than would be expected from adding the selectivities of the RF and IF amplifier stages. These spurious response frequencies are—

- Intermediate frequency response.
- Image response.
- Response at submultiples of the operating frequency.
- Responses due to harmonics of the heterodyning frequency or local oscillator base frequency.
- Responses due to RF harmonics in combination with harmonics of the heterodyning frequency or of the local oscillator base frequency.

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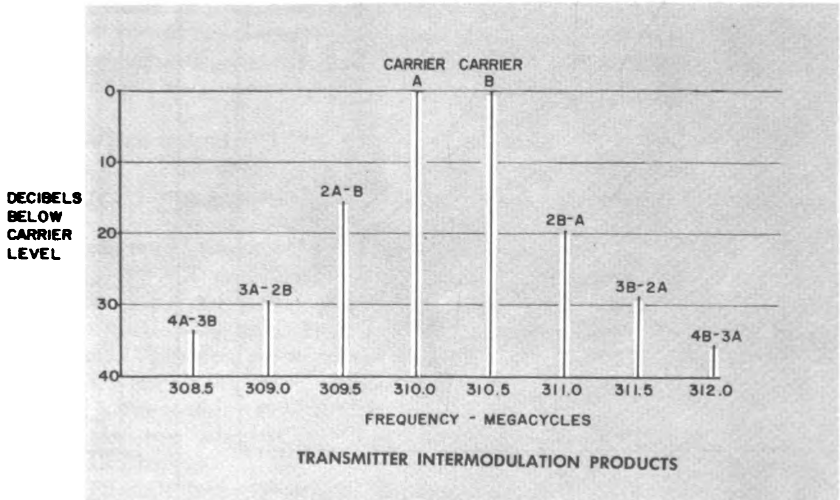
Figure 2. Chart of transmitter intermodulation products, showing decibels below carrier level.



a 5 to 10 db variation in sonar performance figure could pass unnoticed when examined in terms of detection range. This situation is no longer true. At present, 10 db can spell the difference between a totally unacceptable equipment and one that is highly useful.

Unfortunately, the limited data available to the Bureau of Ships from the field indicate that average sonar performance figures are well below design standards both from the standpoint of source level and background noise level.

In reemphasizing the need for absolute quantitative data, it should be added that visual scope observations, qualitative estimates presumably based on experience, are not adequate in relating performances from one unit to the next and can, as has often been demonstrated, provide a completely false picture of the state of an equipment.

At present, modifications to existing equipment to improve source level are under test, which when implemented in the Fleet, will cost approximately $5,000 for each decibel gain.

It would not seem unreasonable, therefore, to expect maximum effort on the part of all concerned in the installation and operation of the equipment toward exploiting the maximum from the dollar investment.

The problem of sonar equipment degradation is one that requires immediate attention. All naval shipyards have been instructed by Bureau of Ships directive to institute sonar performance figure measurements. Also a course of instruction for key installation personnel has been planned.

In addition, a new, permanently installed calibrated sound level meter is expected to be available within the year. With this latter unit, developed by the U.S. Navy Underwater Sound Laboratory and proved in service, the underway measurement phase will be greatly simplified and background noise levels can be read with "the flip of a switch."

Besides the foregoing programs, other steps are being taken to improve sonar performance. Type commanders and Fleet sonar schools are cooperating in indoctrination of sonarmen. Also, the qualifications for sonarmen rate are being revised to require a demonstration of measurement capabilities.

These efforts will without doubt result in measurable improvement in sonar performance.

This article concludes the series on Sonar Performance Figure—The Key to Satisfactory Sonar Equipment Performance.

MODELS AN/BLR-1 AND AN/SLR-2 EQUIPMENT

This article describes a method recommended by the Long Beach Naval Shipyard for calibrating repetition rate scales for IP-10/ULR control unit for AN/BLR-1 and AN/SLR-2 equipment.

This method should be used when regular test equipment prescribed by Instruction Book NavShips 91973 is not available.

The yard states that calibration of repetition rate scales for IP-10/ULR control unit for AN/BLR-1 and AN/SLR-2 equipment may be easily and quickly done by means of the AN/UPM-4A and AN/UPM-70 equipment, normally used with AN/UPX installations.

For AN/BLR-1 and AN/SLR-2 installations aboard destroyer types of vessels, the cable RG-58/U, normally furnished with the AN/UPM-4A, is of adequate length to connect to the IP-10/ULR in the adjacent compartment. On other types of vessels, a longer cable of appropriate length may be quickly assembled aboard ship.

Pulses of 1 microsecond in length are available and repetition rates of 400 and 4,000 PPS are suggested as calibration points. All normal calibration adjustments should be made on the AN/UPM-4A or AN/UPM-70 before attempting calibration of the IP-10/ULR.

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All of the spurious responses may be reduced by increased RF preselection.

Local Oscillator

In a superheterodyne receiver, the fundamental or harmonics of its local oscillator may be present in the input circuit of that receiver. This constitutes spurious energy that may be radiated and cause interference to receivers near by.

Other Considerations

Quite often, additional isolation and substantial improvement in system operation can be realized by careful assignment of frequencies at a given operating facility. Where space attenuation is limited, vertical isolation on UHF and VHF arrays can be used to greatest benefit. In some cases special antennas can be designed to provide further isolation between equipments.

In especially severe cases, such as on shipboard where a separate antenna with each transmitter-receiver combination is impossible, a multicoupler can be used effectively in the UHF region.

As in all things, there seem to be contradictory requirements that can appear in equipment specifications regarding system operation. One of these is a basic "conflict of interest" between obtaining maximum sensitivity and maximum reduction of cross modulation and desensitization. Fortunately, it usually turns out that with a very small sacrifice in receiver sensitivity, a substantial improvement can be achieved with regard to its performance or desensitization and intermodulation.

A working knowledge of the foregoing effects will aid engineering personnel concerned with preparing specifications for radio systems involving the multiple use of equipment in widely varying frequency ranges. With this knowledge, careful planning, and an analysis of the interference problems that may occur, engineers can insure greater return on a given investment.—*Reprinted by special permission from Collins Signal, Winter 1957 issue.*