

# AN ADVANCED INTEGRAL MISSILE EVALUATION SYSTEM

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**Introduction** The total evaluation system of any missile, or other weapon system, must be considered as a whole for the purpose of its establishment and control. A total evaluation system must be applicable to all situations in a missile's life from its preliminary testing to its final operational launching and attack. Typical modes of operation include: research and development, exercise or training, fleet evaluation, and two types of tactical activity, namely -- immediate evaluation including kill probability and damage assessment on the one hand, and on the other, post-firing analysis. The latter includes: jamming detection, missile system failure (either catastrophic or out-of-tolerance conditions of identified components, or sub-systems) due to unreliability, personnel error, or enemy action.

This approach to a total evaluation system has not been the case until recently, when the Department of Defense, through the Navy, established such a program at the Naval Ordnance Laboratory, Corona, with the Fleet Analysis and Evaluation Division. Initially, the project has been concerned with the development of telemetering systems to utilize the new RF band of 2200 -2300 Mc s, mandatory after 1 January, 1970. It is intended that the other armed services shall keep au fait with the NOL/Corona program, and tailor their telemetering systems to be compatible.

**Summary** This paragraph on the total evaluation systems is only being included in order that the position of the telemetering and miss-distance indicating systems may be seen in context. It is not the intention of the author to pre-empt the legitimate concern of other technical groups by describing such system elements as radars, launchers, and weapons control facilities. With this understanding then, the total evaluation system might include:

1. Tracking radars
2. Illumination radars
3. Beam-riding radars
4. Missile weapons direction and NTDS
5. Missile weapons control
6. Missile launcher control
7. Missileborne radar receivers

8. Missileborne guidance system
9. Missileborne homing radar system
10. Missileborne telemetering and MDI (one unit)
11. Shipboard telemetering and MDI station (one unit)
12. Other missile checkout equipment and systems

**An Advanced Integral Telemetering and MDI System** Having set the stage and the context for the telemetering and IFNI sub-system of the total evaluation system, the remainder of this paper will be devoted to the advanced integral telemetering and MDI system, with the total requirements kept in mind.

**The Existing Telemetering and MDI Systems** Since the existing telemetering and MDI sub-systems were developed quite independently, and have been treated separately in the past, a brief evaluation of the telemeter will be made first, and an evaluation of the existing MDI will follow.

Necessarily, since these two sub-systems form part of an active weapon system, full details of their performance and effect on the effectiveness of the weapon system cannot be disclosed. It can, however, be stated that, bearing in mind the fact that the telemetering system as installed must be simple and reliable enough to accommodate all degrees of performance, there are instances recorded where the system has broken down. Easier operating and maintenance requirements appear a necessity, unless the documentation and training can be improved very considerably. The introduction of a newer shipboard station, the SKQ-1, to replace the UKR-10, has effected some improvement.

Present plans to modify the shipboard station for the new higher radio frequency are to retain the existing RF receiver in the SKQ-1, and to insert a preamplifier unit, to operate at the new frequency between the antenna and the SKQ-1. This still leaves the lossy lead-in from the above-deck to below-deck installation carrying radio frequency signals.

The case against the miss-distance measuring system is similar, but stronger. The system, involving the reduction of rather noisy telemetering records, does not give consistent results. It requires three RF heads, and all are operating in the old frequency bands for airborne radio signals. Moreover, since the MDI is not considered a true telemetering system, the use of the 2200-2300 Mc s band is denied to this system. Once again, the performance of certain ships is markedly superior to that of others, which may indicate that documentation and training is inadequate for all levels of competence. The system requires a target beacon, which necessarily bars the use of the existing MDI technique from operational wartime activities. Further, the beacon is too heavy and bulky to be installed in a tactical guided missile without serious loss of weapon system performance.

In summary for both systems, it can be stated that the use of the FM/FM system for the telemetered links, and the absence of the features of modern packaging, (extreme reliability, low cost in mass production, and greatly reduced size and weight) together with the reliance on the lower RF band, makes a new approach long overdue.

## **An Advanced Integral Telemetry and Miss-Distance Indicating System**

**1. Purpose** The proposed advanced integral telemetry and miss-distance indicating system is intended to achieve, among others, the following objectives:

- a. To restore the missile telemetry from “the-state-of-the-ark” to “the-state-of-the-art”.
- b. To provide a tactical system for missile performance evaluation from launch to near intercept (T-1 millisecond approximate).
- c. To provide all-weather tactical miss-distance and (possible) burst observations.
- d. To eliminate requirement for target instrumentation.
- e. To eliminate requirement for target/ship radio link.
- f. To utilize the shift from the RF band of 215-260 Mcs to the new 2200-2300 Mcs RF band as effectively as possible.
- g. To provide a single combined telemetry/miss-distance indicating link using only one RF shipboard receiver head (replacing existing four RF heads). For “true Doppler” operation, two heads will be necessary.
- h. To reduce missile-borne systems in complexity, weight, size, and power requirements, while increasing their reliability and reducing their cost.
- i. To obtain minimum warmup time (1-2 seconds maximum) for airborne systems.
- j. To reduce to a minimum the shipboard receiving station equipment, and to eliminate the lossy RF lead-in.
- k. To (possibly) augment or replace existing homing guidance systems over all -- or at least the final portion of -- the missile’s flight path.
- l. To accommodate more than one missile in flight simultaneously.

## **2. System Details.**

- a. Missile Transmission System - Telemetry
  - (1) Telemetered data points
  - (2) Clock and gating matrix
  - (3) Electronic commutator
  - (4) Analog oscillator
  - (5) RF transmitter
    - (a) Modulator
    - (b) Master oscillator
    - (c) Amplifier

- (d) Frequency multiplication chain
- (e) Final power amplifier and cavity
- (f) Antenna and feeder
- b. Shipboard Receiving System - Telemetry
  - (1) Antenna and feeder
  - (2) Close-mounted receiver
    - (a) RF head for 4 links
    - (b) 4 RF amplifiers
    - (c) 4 Mixers and 1st RF
    - (d) 4 mixers and 2nd RF
    - (e) 4 PH/LL PH demodulators
    - (f) 4 comb filter banks
    - (g) Demultiplexers
  - (3) Below Decks equipment
    - (a) Predetection recording
    - (b) Multiple recording
    - (c) Multiple display

c. The Miss-Distance Indication Problem In the life cycle of a guided missile, there are a number of flight possibilities which require total evaluation as described in the Introduction. Training, exercise, and fleet evaluation programs require some form of MDI. In a tactical situation, there are two considerations in connection with the use of an MDI system.

- (1) Immediate operational information must be made available to the firing ship and to other ships of the fleet.
- (2) Information of use in operations research type evaluation and analysis after the event includes evidence of enemy jamming and missile malfunctioning due to:
  - (a) long or short term unreliability,
  - (b) friendly interference,
  - (c) unusual weather conditions, and
  - (d) other indeterminate influences.

Both of these types of information would be available from the advanced integral telemetry system, operating as the major link, and possibly the only link, between the missile/target combination and the ship or ships concerned.

d. Alternative Solutions, including Alternative Guidance Systems. The present MDI system uses a beacon in the target and two airborne-to-ship links -- one the link from missile-to-ship using a telemetry transmitter and receiver, and the other the target-to-ship employing a special frequency band. Obviously, in a tactical situation, the use of a beacon in the target is prohibited. Therefore, two solutions for an immediate tactical

MDI system are presented, and a third solution is suggested for other than tactical operation.

(1) Infra-Red TV Scan MDI. -Measurement of miss-distance under tactical conditions can be accomplished by mounting an infra-red TV scan system in the missile. One inch vidicon elements having a 60 degree scan angle and 23 micron maximum sensitivity are available for this purpose. The cameras can be oriented for the required full coverage of the forward-looking direction as the missile approaches the target. The video signal resulting from the continuous scan could be introduced directly to the telemetering transmitter modulator. However, bandwidth requirements are minimized in the missile-to-ship telemetry link if data redundancy is removed. The shipboard receiving equipment would utilize part of the advanced integral telemetering equipment, and in comparison with the present system, would require only one RF receiver head in place of the three now required. The infra-red TV system would, of course, eliminate all the ship-based units indicated in Figure 3, with the possible exception of the circuitry used to calculate and present miss-distance values. The vidicon installation also has the potential to supply adequate homing signals to replace the present radar homing guidance. In this instance, it would also then be possible to dispense with the illuminating radar. Target damage assessment, if required, can be achieved by utilizing a very small sub-rocket, ejected from the missile just prior to warhead detonation. This sub-rocket, instrumented with an infra-red sensitive mosaic, will record and pinpoint each warhead hit on the target by virtue of the infra-red flash developed at each impact. It is necessary to hold the rocket a safe distance from the warhead to avoid damage by the concussion. The sub-rocket also requires a transmitter for sending the mosaic patterns to the ship. This would require an additional radio frequency head and other ship-based equipment. These infra-red techniques for hit detection have been proven in actual flight operation for micro-meteorite impact on a satellite by NASA. The infra-red offset rocket technique has also been demonstrated satisfactorily.

(2) Advanced Radio Doppler MDI. -An alternative to the TV system employs a very stable oscillator (one part in  $10^7$  stability) to phase modulate a second RF transmitter, which could be an additional final stage to the integral transmitter. This transmitter would excite an antenna lens to direct a signal at the target, where it would be reflected to the ship-board or ground-based station. Since it is undesirable for a radiation to be beamed at the target until the last few seconds of the attack, the actual excitation of the lens must be attenuated until the final stages of homing raise the power of the antenna to the required level. There is always some backward scatter from any lens or antenna. The integral telemetering transmitter antenna is no exception. Therefore, if the tactical telemetering program is adopted, the telemetering radiation would occur during the entire missile flight from launch to warhead detonation. The MDI telemetering transmitter previously described, excited by the stable oscillator, could be used to provide a canceling signal radiation of this backward scatter. Sudden raising of the NMI

power level would overcome the balanced condition of the two radiations and illuminate the target as required. Figure 2 indicates the target beacon arrangement for the advanced radio doppler MDI version. Figure 3 indicates some of the possibilities for the airborne systems, as well as alternative ship-board stations to accommodate the above MDI techniques.

(3) Present MDI System. -For normal training and evaluation MDI usage, the present system as described above can be used. However, the packaging can be updated to the state-of-the-art as described in the telemetering section.

**3. Packaging Techniques - Telemetering** The entire missile-borne telemetering transmission system with the exception of parts of the RF transmitter could be fabricated, utilizing microelectronics. Advantages to be gained through the use of microelectronics include:

- a. Reliability - approaching 100 per cent.
- b. Low cost of mass production (72 audio-amplifiers on a single substrate are available at an approximate cost of 20 cents per amplifier.
- c. Extreme miniaturization, and weight and power reduction.
- d. Improved wiring power handling capability by use of microstrip consolidated cables.

The entire airborne packaged unit can be divided into sub-units or it can be manufactured as a whole. In either case, the smallest visible parts would be “throw-away” units, by virtue of their very low cost. This should reduce very considerably the time and cost for maintenance and training for maintenance.

It appears feasible to install the entire telemetering (and miss-distance) shipboard receiving package at the location of the broad-band receiving antenna. This package would terminate with output lines to the various recorders, display units, and inputs to the fire control computers, all situated below deck. Thus, all signals other than audio-signals would be eliminated from the antenna feed through link, and greatly reduce interference and other signal losses. Frequency selection in the 2.2 to 2.3 Gc s band can be accommodated by remote control. The proposed advanced telemetering receiver could achieve the frequency changes by either switching crystals or by mechanically controlled continuously changing frequency techniques. Similarly, the comb filters could be switched since their characteristic frequency band is determined by a single capacitor in the VCO of the servo loop for each filter element.

**Component Details of System - Telemetering** A pulse amplitude modulated/phase modulated (PAM/PM) telemetering system is proposed which utilizes modern integrated circuits. The 50-channel, solid-state, electronic switching, matrix commutator operates at a 50 or 100 samples per second rate. A single analog oscillator phase modulates an RF

transmitter operating in either 220 or 2200 Mc band. The transmitter drives a rear-directional antenna.

To mask forward scatter, a second RF transmitter, at a second frequency, can utilize the same lens to interfere with scatter, and to provide subtle jamming as “garbled” telemetering intelligence.

The shipboard receiver station proposed utilizes a phaselock PAM/ PM receiver covering either the 216-260 Mc or the 2200-2290 Mc band. A comb filter is incorporated to improve data accuracy. Demodulation and display facilities provide for the display of each data channel as a varying waveform or by an indicator light. All telemetered functions are recorded for post-test analysis and use. Real-time control of weapons systems can be derived from the telemetered functions, if required.

An additional capability can be provided to transmit the video Doppler, either continuously as a true modulation of the RF transmitter, or at a high sampling rate. This involves modification to the comb filter unit to cover the additional frequency spectrum.

**Advantages of the Proposed Telemetering & MDI System** The proposed system offers increased reliability, reduced weight and size, and advanced low-cost packaging techniques. The total missile-borne system is suitable for tactical use.

The proposed system will be designed to operate in the new RF band of 2.2 to 2.3 Gcs, which is obligatory as of 1 January 1970. Although 1970 is five years away, at least three years will be required in the writer's opinion, after successful development and production of the new frequency units are achieved, to indoctrinate the operating personnel in the use of radically different techniques for installation/check-out operations and maintenance necessitated by the higher frequency components.

The present system is inadmissible for use in military operations because of the excessive warm-up time required. The proposed system components with warm-up times of one to two seconds are believed satisfactory for all foreseeable situations.

The physical separation of the present telemetering shipboard antenna and the receiving station results in excessive signal-to-noise problems, and renders the system liable to many types of interference. The proposed system, which is considered to be sufficiently compact to allow for its mounting (down to the demultiplexers) on the antenna location, on the other hand, will not be subject to the above limitations. Moreover, the virtually continuous metallic path on one basis substrate of the RF receiver, IF's, demodulators, comb filter banks, and demultiplexers will produce standards of reliability, of lack of

interference, and of low production cost, which have hitherto not been attempted in these programs.

In conformity with the philosophy of total evaluation systems, the telemetering and miss-distance indicating systems just described in this paper utilize common elements in many instances. This commonality minimizes the problem of training, the effort for documentation, and the logistics of supply and maintenance.

The provision of a truly tactical "flight-test" style capability significantly alters the degree of effectiveness, and in consequence, the level of protection, which the missile system can afford the fleet. This becomes even more important as the size of the weapons is increased, and hence, the number which a given ship can carry is correspondingly reduced.

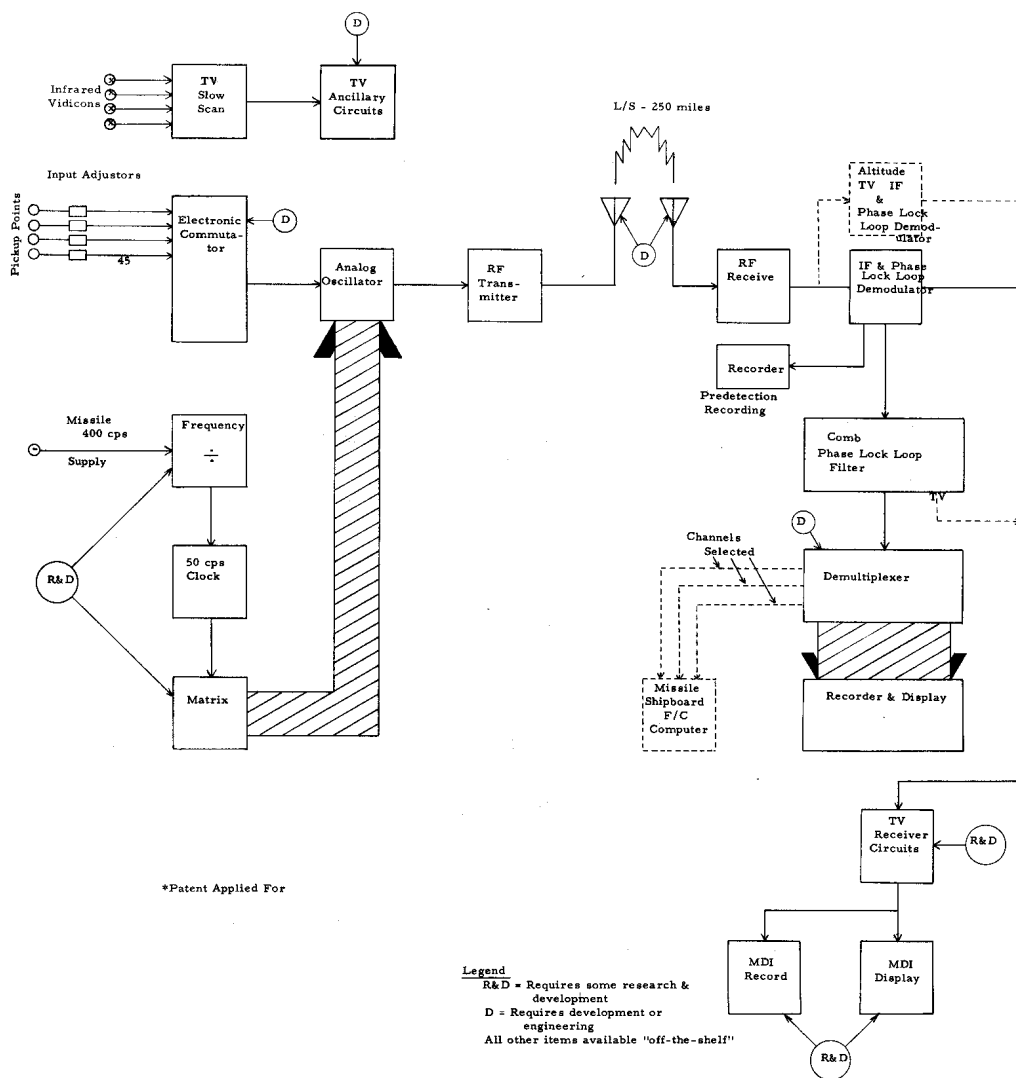
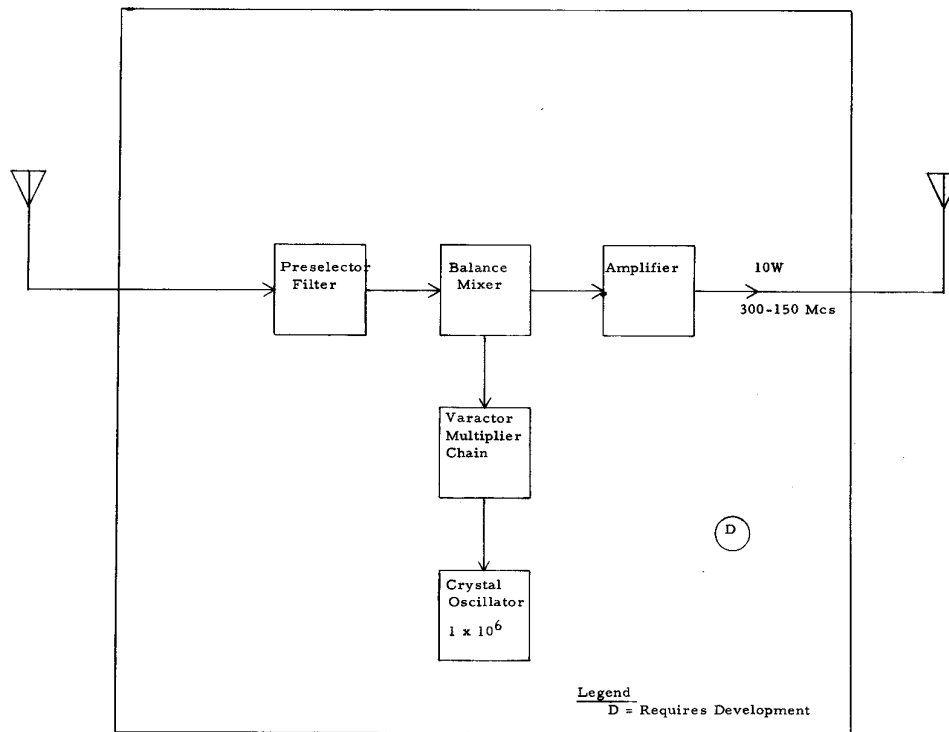


Figure 1. -Advanced Telemetering and TV/MDI Tactical Systems Block Diagram





**Figure 2. -Advanced Radio Doppler MDI - Target Beacon with Target/Ship MDI Link**